Climate Change Impacts on Human and Ecosystem Health in Cuyahoga County

Mitigation and Adaptation Strategies

2021

Acknowledgments

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Did you know that Cuyahoga County shares a common international boundary with Canada? Along with 457 square miles of land (37%), the County also includes approximately 788 square miles (63%) of surface area located beneath the waters of Lake Erie. Cuyahoga County has a total surface area of 1246 square miles and is the 2nd largest county in Ohio.
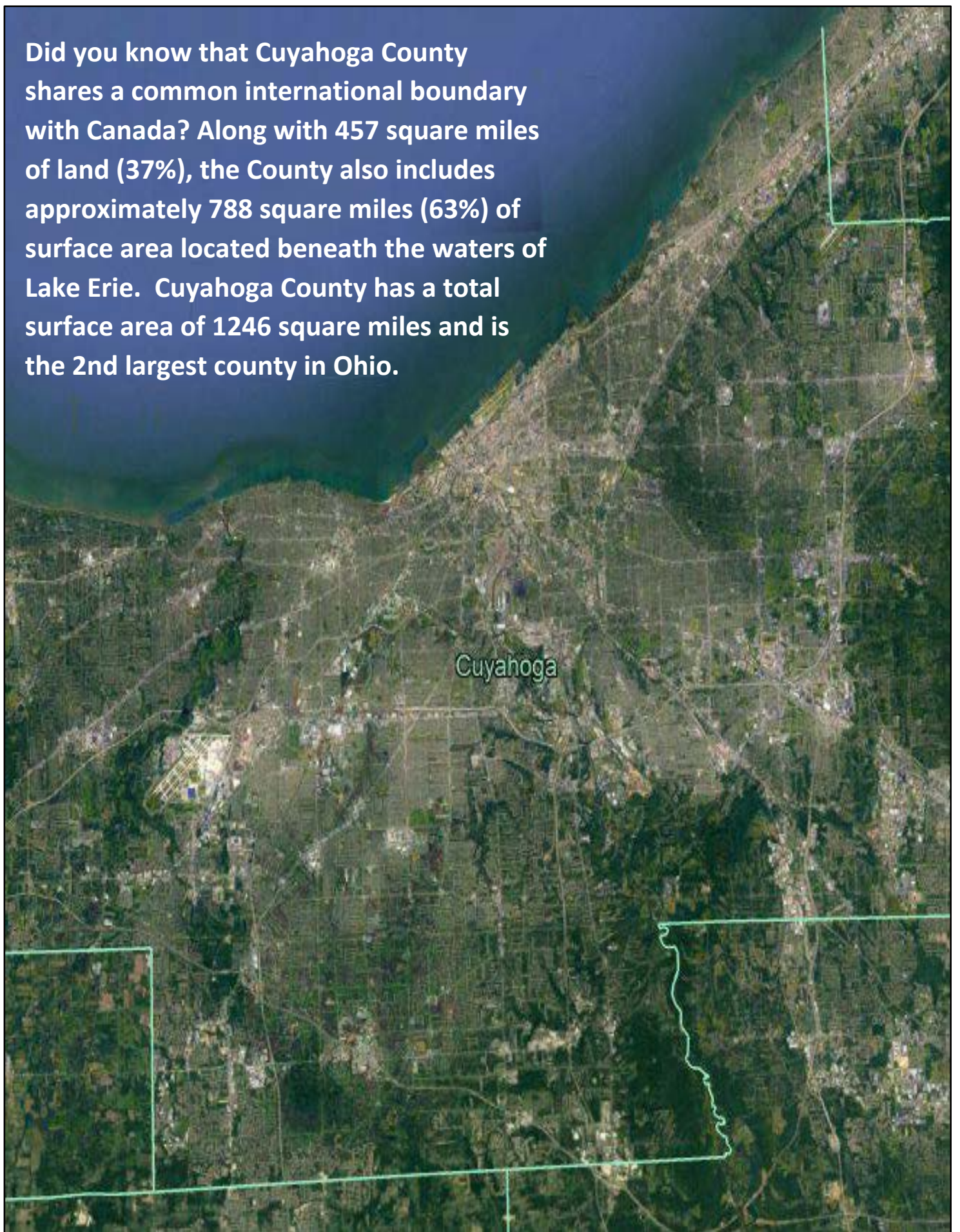
Cuyahoga

Table of Contents

Note

The primary intent for compiling and promoting this document is to provide a basic summary of climate change and the impact it has on human and ecosystem health. For a quick review of basic terms, concepts and definitions associated with climate change, it may be beneficial to first review the information provided in the appendices.

Appendix 1 discusses basic concepts and provides definitions for terms discussed throughout the document. Appendix 2 provides more detailed information on ecological perspectives, which encompass much of the human endeavor and urban living.

The Mitigation and Adaptation Strategies identify six key areas which will undergo the greatest impacts from climate change. Illustrations provided represent and support concepts in the text. The references provided in this document are only starting points. The bibliography is not intended to be definitive, but rather to point the reader to documents that are either primary, or the most recent sources of information. It is important to remember that although the research and preparation for this document began in a time frame prior to the COVID-19 pandemic, its completion was impacted by our agency's focus on providing extensive pandemic response to help protect the health of those who live, work and play in Cuyahoga County. More recent work has continued to be published, thus making some of the suggestions appear dated.

Hopefully, the information provided and the strategies proposed will help in your endeavors to mitigate the effects of climate change that impact your community, your family or your own personal well-being.

Approximately 12,000 years ago, glaciers scraped and scoured the land-surface and created the sinuous rivers, steep-sided valleys and altered the watershed and drainage for the Cuyahoga, Chagrin and Rocky Rivers. These three main Cuyahoga County rivers draining into Lake Erie.

The above aerial photo supports why local Iroquoian native Americans named the river "Cuyahoga", which means "crooked river".

EXECUTIVE SUMMARY

CUYAHOGA COUNTY OVERVEW

While public health entities are challenged with the task of protecting human health and the environment, it is important to recognize that the changing climate will add additional stress and exacerbate risks that will impact human health and ecosystem functions. It is in this context that the Cuyahoga County Climate Change Action Plan (CCCCAP) and this Cuyahoga County Climate Impacts on Human Health: Mitigation and Adaptation Strategies, have been compiled. Both documents incorporate methodologies based in ecology and sociology and provide mitigation and adaption strategies. Ongoing education combined with the adoption of beneficial policies are needed to reduce the increasing effects of climate impacts on human health and ecosystem health.

A study was commissioned to assist Cuyahoga County identify all forms of emissions, and levels of CO_2 (Brendle Group, 2018). The detailed results are available in the Cuyahoga County Climate Change Action Plan (CCCCAP), which identified that total emissions for Cuyahoga County decreased by 10% between 2010 and 2017. However, emissions from transportation in the County increased by 9% for the same time period. Of these emissions, 78% were from passenger vehicles and made up 93% of all vehicular miles traveled (VMT) in Cuyahoga County. The total emissions provide baseline values for the CCCCAP as it looks to reduce emissions, provide data to identify vulnerable communities and determine resilience strategies to minimize the impacts of climate change.

The information provided in this document offers measures to protect human health and strategies that will improve ecosystem and human resilience against climate impacts. Modeled after existing federal, state, county, and international climate impact strategies, six primary focus areas have been identified.

OVERVIEW AND OBJECTIVES OF STRATEGIES

The Climate Impacts on Human Health: Mitigation and Adaptation Strategy identifies six focus areas, which are the major contributors to health impacts:

- Extreme Weather
- Food Safety, Nutrition and Access
- Vector-Borne Diseases and Epidemiology
- Water Supply and Waterborne Illness
- Air Quality
- Mental Health and Well-being

Two appendices also provide additional key concepts:

- Appendix 1. Climate Change 101: Key Concepts.
- Appendix 2. Ecology and Trees.

To protect human health against the impacts of climate change, ways of reducing emissions (mitigation measures) and building resilience (adaption strategies), are provided after each of the six sections.

Some of the focus areas may require both mitigation and adaptation, while for some areas, only adaption measures may be suitable.

Impact of Climate Change on Human Health
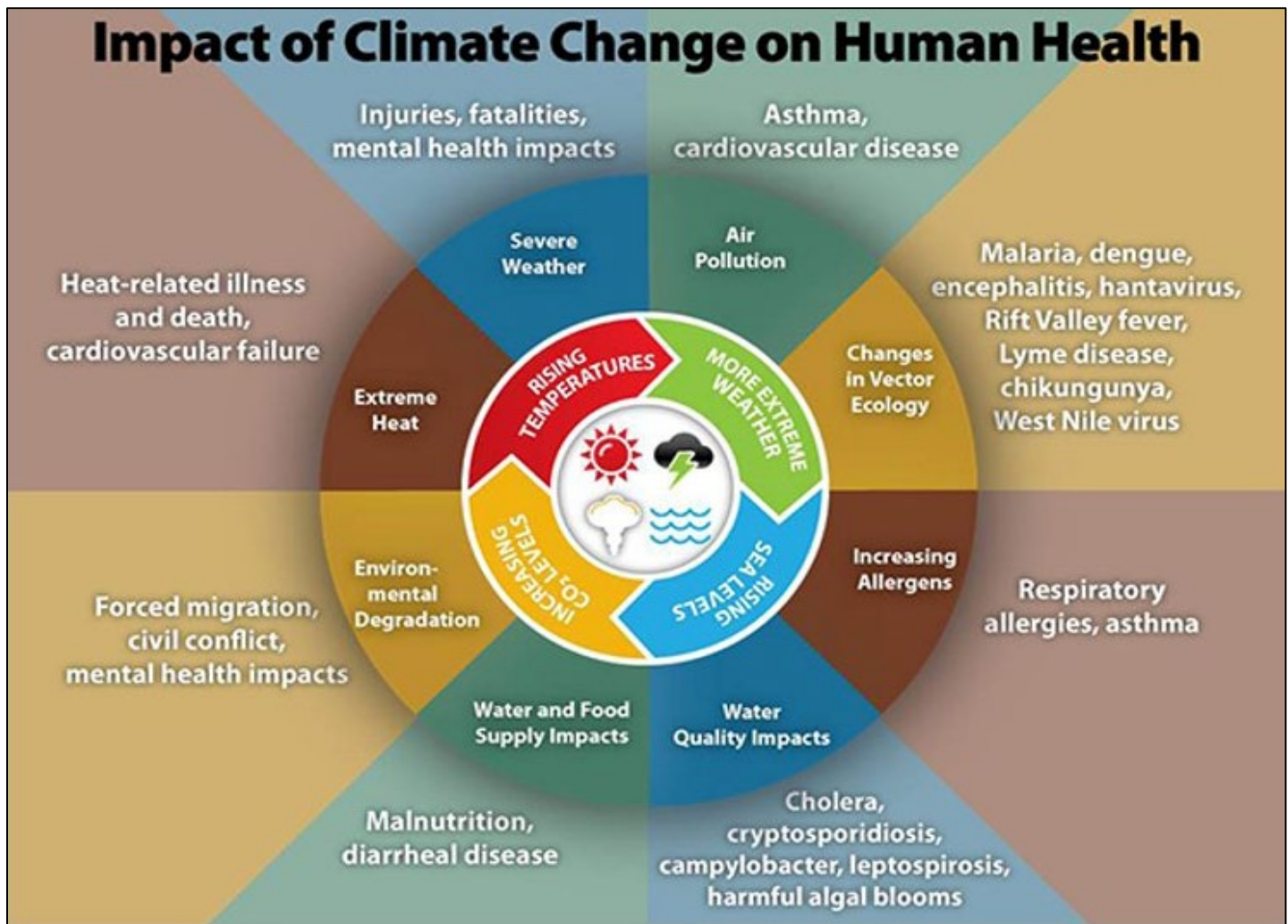
- **Extreme Weather:** Daily temperatures are increasing due to rising CO_2 levels, making more energy available to contribute to bigger, more intense storms. These extreme weather events will cause more intense rainfall in shorter periods of time, increased storm water runoff, flooding, and as a result lead to an increased number of drownings. Extreme weather will damage buildings and infrastructure, which will impose greater stress on the ecosystem services and human health. More people die from extreme heat than extreme cold. Extreme heat may also potentially lead to increased violent crime, heat-related deaths, and illness. The populations most vulnerable to the extreme temperatures include those of a lower income level, people experiencing homelessness, infants and children under the age of five, the elderly, outdoor workers, and those residing or working in environments without adequate cooling opportunities or air conditioning.

These susceptible groups will be more affected

by the urban heat island effect. Predictions for climate-induced, extreme weather indicate those seeking refuge to the U.S. will most likely increase. These numbers will be added to by internally displaced U.S. residents moving from coastal areas suffering sea-level rise, tornadoes, flooding, drought, or economic hardship to safer, more stable areas. It is likely that as demand for access to freshwater increases, displaced people will move to the Great Lakes Region. This will in turn impose increased demand on infrastructure, food supplies, and Great Lakes water. Improving ecosystem function and biodiversity will add increased resilience to climate change impacts. Examples include reducing the amount of semi-permeable and impermeable surfaces, the planting of trees, etc.

- **Food Safety, Nutrition and Access:** Cuyahoga County is highly urbanized, with limited commercial agriculture, unlike other regions of Ohio. The influence of climate change on food locally may not be related directly to agricultural production, but more

to food security. This includes a number of factors, such as rising temperatures resulting in increased food-borne disease, chemical contamination of food by the use of pesticides and herbicides, plastics leaching into soil and water, rising CO_2 levels lowering nutritional value of foods, and extreme weather, which could impact transportation and distribution thus limiting access to quality food. Eating locally grown food reduces emissions associated with lengthy transportation and importing food, as well as providing improved food nutritional quality when compared with industrial scale farm-produced foods.

- **Vector-Borne Disease and Epidemiology:** Climate change is increasing seasonal length and growing period conducive to the proliferation of pests. It is also altering geographic conditions, which in turn, will expand the range of vectors and vector-borne diseases. In Ohio, this is already of concern, with an increase in arthropod (mosquito and tick-borne) diseases. Lyme disease, Zika, West Nile Virus, and Malaria will become even a greater concern in our region. There will also be an increase in travel-related tropical diseases such as Dengue Fever, Ebola, and Chikungunya.

- **Water Supply and Waterborne Illness:** The Great Lakes, including Lake Erie, hold approximately 20% of the worlds' freshwater. Drought will not be a primary threat to the region. Instead, climate change will affect freshwater quality and increase the potential for waterborne diseases. Extreme weather events will increase flooding and waterborne disease-producing pathogens. Water-related illnesses caused by toxins produced by harmful algae and cyanobacteria (blue-green algae) blooms will increase in Lake Erie. Drought elsewhere in the nation, along with the need for water dedicated for agricultural purposes, will increase demands for diverting the Great Lakes freshwater. Reducing nutrient runoff into Lake Erie can help decrease toxics algal blooms and improve water quality. Additional adaption measures include; reducing the use and manufacturing of plastics, especially single-use items, recycling plastics, and increasing the manufacturing of non-oil based plastics.

- **Air Quality:** Air pollutants and emissions pose a threat to human health, particularly to infants and young children, the elderly, asthmatics, and chronic lung disease sufferers. Harmful vehicle emissions include soot (solid particulate matter), Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O) and Hydrofluorocarbons (HFCs), all of which may

contribute to the increased incidence of asthma. Climate change plays a role in the prevalence and severity of respiratory diseases, which will be exacerbated by poverty, city living, air pollution from emissions, and ground-level ozone. There will be increases of allergies to pollen and fungal spores as the growing season lengthens for plants such as ragweed. Adaptation measures include reducing air pollutants and improving air quality by increasing regional mass transportation, the use of hybrid and electric vehicles, and sequestration of carbon generated by emissions through the increased planting of trees.

- **Mental Health and Well-being:** The threat of climate change and extreme weather events may increase anxiety, stress, and a sense of helplessness. People typically feel strong emotional responses to such events, while watching television coverage or reading about these events, which ultimately has a direct negative effect on human health and well-being. Vulnerable groups include infants, young children, the elderly, the poor, those who suffer from Prolonged Duress Stress Disorder (PDSD) and Post Traumatic Stress Disorder (PTSD). First responders, emergency workers, those with mental health issues, and the hospitalized are examples of groups who may suffer from these disorders. Increased exercise, including walking in natural settings and enjoying the environment, and are known to improve physical health and one's sense of well-being.

Solar Panel Installation on Brooklyn Brownfields, Cuyahoga County. This 4.0 MW array was constructed on approximately 17 acres of a 75-acre former landfill site and is designed to generate over 5,000,000 kWh of electricity annually. It can provide approximately 8% of the electrical consumption for 10 County-owned buildings (Resource from the CCCCAP).

COUNTYWIDE MITIGATION AND ADAPTATION STRATEGIES

Increasing the use of solar and wind energy will help reduce emissions. The expansion of transit systems and biking connectivity, installation of additional sidewalks to allow for walking in neighborhoods and the increased use of electrical and hybrid vehicles, along with reductions in single occupancy vehicle use, will do the same. Increasing parks and open spaces by expanding the existing Trails and Greenways Plan, and planting 500,000 trees by the year 2040, incorporate both adaptation and mitigation strategies. These actions will ensure ecosystem services, sustainability, protect biodiversity, relieve climate-related anxiety and augment human health, including mental and physical fitness. Strong leadership is required to implement policies and facilitate the paradigm shift needed to ensure that proper levels of human health and well-being are maintained. Education is essential to achieve these goals. (Anderson, 2012, Boakye, 2015, Monroe et al., 2017, National Centre for Science Education (NCSE), 2019.

Currently, meetings are held on an adhoc basis to assess progress in reducing emissions and the five other management focus areas detailed in the Cuyahoga County Climate Change Action Plan. These include Energy, Transportation, Natural Systems, Human Health, and Land Use. Members will review and monitor progress on adaptation and mitigation strategies. These meetings allow for flexibility in assessing how well various aspects of the Plan are developing and will assist in identifying any required changes or additions. The Cuyahoga County Board of Health will have a representative at these meetings to provide updates on the progress of this Mitigation and Adaptation Strategy.

References

- Anderson, A., 2012. Climate Change Education for Mitigation and Adaptation. SAGE Publications, (Los Angeles, London, New Delhi, Singapore and Washington DC.) Vol 6(2): 191-206. 10.1177/0973408212575199 www.sagepublications.com.
- Boakye C., 2015. Climate Change Education: The Role of Pre-Tertiary Science Curricula in Ghana. SAGE and Open Access pages, 1-10. DOI: 10.1177/2158244015614611 sgo.sagepub.com (https://us.sagepub.com/en-us/nam/open-access-at-sage).
- Monroe M.C., Plate R.R., Oxarart A., Bowers A., and Chaves W.A., 2017. Identifying effective climate change education strategies: a systematic review of the research, Environmental Education Research, DOI: 10.1080/13504622.2017.1360842.
- National Centre for Science Education (NCSE), 2019. Teaching Climate Change: Best Practices: https://ncse.com/library-resource/teaching-climate-change-best-practices.

INTRODUCTION

What is the difference between Global Warming and Climate Change?

Although these terms are frequently used interchangeably, "Global Warming" and "Climate Change" are not the same thing. These terms have different meanings to different people. Global Warming is one component of a much larger problem of human-caused (anthropogenic) Climate Change.

The term "climatic change", now termed "climate change", and the connection with rising CO_2 levels and increasing temperatures, was first described in a peer reviewed scientific paper by Gilbert N., Plass in 1956 titled; 'The Carbon Dioxide Theory of Climatic Change'. He predicted that the warming trend from increased CO_2 levels would last for several centuries. He identified three main factors responsible for the earth's atmospheric CO_2 balance – the organic world (photosynthesis; decay and respiration), the inorganic world (weathering of igneous rock; volcanoes) and man's activities (combustion of fossil fuels; clearance of forests; cultivation of land).

The term "Global Warming" was first used by Wallace S., Broecker in his 1975 peer reviewed publication, 'Climatic change: Are we on the Brink of a Pronounced Global Warming?'

In the years since Plass' 1956 paper, the advancements in computer supported atmospheric, oceanographic and meteorological sciences has improved the ability to collect, measure, assess, analyze and describe large quantities of data. The improvements in science, with the availability of more data, allowed Broecker in 1975 to write; "The fact that the mean global temperature has been falling over the past few decades has led observers to discount the warming effects of CO_2 produced by burning chemical fuels" (Broecker, 1975, PP 460). Broecker's calculations showed that if CO_2 levels continued to rise, the predicted temperature

increase by 2010 would escalate by 1.10 ˚C (1.98 ˚F) with atmospheric CO_2 concentrations of 403.0 parts per million (ppm). His 1975 calculations are remarkably accurate, as the global temperature escalation recorded in 2010 was 0.73 ˚C (1.3 ˚F). The Year 2010 was the warmest year on record, with atmospheric CO_2 levels measured at 393.0 ppm. Broecker had estimated 403 ppm (NOAA.gov). In June 2019, global surface temperature had increased by 1.34 ˚C (2.41˚F) above the 20th century average, the highest in the 140-year record. It exceeded the previous record of +1.30 ˚C (2.34 ˚F) set in 2015 (NOAA.gov). In June 2019, atmospheric CO_2 levels measured 415.0 ppm, the highest ever recorded (Weekly January 16, 2022, Mauna Loa CO_2 average: 417.4 ppm).

Another way of understanding these numbers is by finding out how much CO_2 is put into the atmosphere per year by human-caused burning of fossil fuels. The 2018 paper by C. Le Quere et al., (Global Carbon Budget 2018) estimated that the global atmospheric addition of CO_2 was 32.6 gigatons! The total contribution for U.S. energy-related emissions for 2017 was 5.5 gigatons of CO_2 added to the atmosphere (eia.gov, 2018).

References:
Climate change in America mind.
https://climatecomminication.yale.edu.

Plass, G.N., 1956. The Carbon Dioxide Theory of Climatic Change. Tellus VIII (2), pp 140-154. https://onlinelibrary.wiley.com doi abs j.2153-3490.1956.tb01206.x

Broecker, W.S., 1975. Climate change: Are we on the Brink of a Pronounced Global Warming? Science 189(4201), 460-463. http://doi.org/10.1126/science.189.4201.

Climate Change in Cuyahoga County

The climate is changing, the effects of which are becoming more apparent with increased frequency of "100 year" and "500 year" storms now occurring much more frequently. The result is more destruction and detrimental impacts on human health. The impacts of climate chance are already being manifested in Northeast Ohio with increased temperatures and precipitation, changes to ice cover on Lake Erie, and changes to the regional growing season (GLISA, 2014).

The exponential increase of Greenhouse Gas emissions into the atmosphere has warmed the earth more than 1°C since the start of the industrial revolution. Global emissions continue to rise as the energy sector is predominately fossil-fuel based. The urgency to act now is highlighted by the latest Intergovernmental Panel on Climate Change (IPCC) report issued in September 2018. This report indicates that the goal of maintaining the global temperature rise to under 2°C proposed by the Paris Accord in December of 2015, is too high a risk, and has been revised to reflect a lower mark of 1.5°C. This would set the U.S. goal of 26%-28% emissions reduction below 2005 levels by the year 2025.

The 2018 IPCC report stresses even greater urgency in reducing CO_2 emissions and the immediate need to implement climate change adaption and mitigation strategies. The severity of extreme weather events depends on what we now do to reduce emissions to mitigate and adapt to climate change. The IPCC projects that we will experience up to 5.8°C of warming by the end of the century if drastic measures to mitigate emissions are not taken (Leahy, 2017).

The report makes clear that half a degree matters and that the global temperatures must be kept from rising above 1.5°C to avoid catastrophic changes to the Climate. Greenhouse gas emissions would need to be cut by 45% below 2010 levels by the year 2030 and reaching net zero emissions by 2050 (Lewis, 2018).

Photo credit: https://news.brown.edu

Visualization of one ton of CO_2. Annually, emissions add 36 billion tons to the atmosphere.

As a direct result of the United States pulling out of the Paris Climate Agreement in July 2017, Cuyahoga County and the City of Cleveland signed the **Global Covenant of Mayors for Climate & Energy**. They joining local governments across the world, in a commitment to measure, track, and reduce greenhouse gas emissions and prepare for the impacts of climate change. The Cuyahoga County Climate Change Action Plan (CCCCAP) was produced as a direct result of this Covenant. The CCCCAP also aligns with the goals of the United States Climate Alliance's core principles, located at www.usclimatealliance.org.

To date, the State of Ohio has not implemented a Climate Change Plan. In the future, it will be prudent for Cuyahoga County to consider forming coalitions with adjacent counties to provide recommendations on how to manage climate change and the resulting impacts on human health on a wider, regional scale. This type of coalition exists in other parts of the country, as in the State of Florida, where four counties (Broward, Miami-Dade, Monroe, and Palm Beach) have created the Southeast Florida Regional Climate Change Compact in order to coordinate adaptation and mitigation strategies.

CUYAHOGA COUNTY'S CHANGING CLIMATE

The CCCCAP provides details on five major areas that will have the greatest effect on reducing emissions and as a result, have a direct impact on climate change. These include Energy, Transportation, Natural Systems, Human Health, and Land Use.

In addressing the topic of climate change, there are key questions and concepts that must first be defined and explained. These are presented in two appendices at the end of the document.

Appendix 1. Climate Change 101: Key Concepts and Definitions. Seventeen essential terms and concepts are defined and explained, including the Greenhouse Effect, and Greenhouse Gases (GHG's).

Appendix 2. Ecology and Trees: Ecosystems, Ecosystem Services and Biodiversity. This Appendix provides insight into the importance of ecology and human health. It is divided into six sections:

1. Watershed—rivers, streams, and Lake Erie
2. Vegetation—urban forests, trees, and biodiversity
3. Human Health and urban ecology
4. Trees
5. Lawns
6. Environmental Management and Ecological Restoration

One example, the planting of trees, has a wide range of potential beneficial impacts. These include the reduction of storm water runoff, flooding, the heat-island effect and crime; improving human health; increasing biodiversity; lowering temperature; increasing humidity under the tree canopy; and the sequestering of carbon.

A current local proposal includes the planting of 500,000 trees throughout Cuyahoga County by the year 2040. Details are available in the Cuyahoga County Greenprint Guidebook (https://www.countyplanning.us/wp-content/uploads/2016/03/greenprint_guidebook.pdf). An additional reference is the City of Cleveland's Tree Plan (Cleveland Tree Coalition, 2018). It can be found at:

http://www.city.cleveland.oh.us/sites/default/files/forms_publications/ClevelandTreePlan.pdf.

OBJECTIVES OF THE CLIMATE IMPACTS ON HUMAN HEALTH: MITIGATION AND ADAPTATION STRATEGIES

The overall goal of this document is to promote Mitigation and Adaptation Strategies in response to climate change impacts which also align with the aim of the CCCCAP. There are five main objectives for these Mitigation and Adaptation Strategies:

A. To inform human health care professionals, government personnel, policy-makers, health care providers and the residents of Cuyahoga County on human health risks due to climate change.
B. To identify vulnerable populations who are at greater risk from the effects of climate change.
C. To identify and consider implementation of both mitigation and adaption strategies. Data will be evaluated to determine if the efforts need to be shifted from mitigation, to focus more on adaptation, and the provision of best-practice strategies to protect human and ecosystem health.
D. To inform emergency response organizations, planners and other pertinent entities of the potential health consequences of climate change thus allowing them to develop and implement appropriate plans to address these predicted events.
E. To expand these strategies regionally forming a foundation for statewide Mitigation and Adaptation Strategy development.

In order to implement mitigation and adaptation strategies, six key areas which will suffer the greatest impacts from climate change have been identified:
- Extreme Weather
- Food Safety, Nutrition, and Access
- Vector-Borne Disease and Epidemiology
- Water Supplies and Waterborne Illnesses
- Air Quality
- Mental Health and Well-being.

Mitigation and adaptation strategies are identified and incorporated at the end of each of the six sections. Education of local leaders as well as the public, along with the adoption of appropriate policies, will be necessary if these strategies are to be considered for implementation.

Linking ecological and sociological methodologies is a logical combination of scientific disciplines, which enhances the current understanding of urban ecology, the built-environment, ecosystem services and human health (Schwarzman, 2002). A more holistic view is required, to include the living (biotic) and non-living (abiotic) components. It must also account for how human actions are modifying ecosystems and as a result impacting human health and well-being.

References:

- Boecker, W.S., 1975. Climate Change: Are We on the Brink of a Pronounced Global Warming? Science, New Series, Vol. 189, No. 4201, pp. 460-463.
- Climate Change in the Great Lakes Region, (GLISA, 2014). Retrieved from http://glisa.umich.edu/media/files/GLISA_climate_change_summary.pdf
- 'Climate Change is the greatest threat to national security we will have to face', Bernie Sanders, Fact checked by Linda Qui 14th November 2015, 4.38 p.m.
- Climate Literacy: http://oceanservice.noaa.gov/education/literacy.html
- Understanding Climate Change: http://www.climate.gov/#understandingClimate
- Cuyahoga County Board of Health: http://cuyahoga.oh.networkofcare.org/ph/county-indicators.aspx?t=hp2020,green,lightgreen,yellow,orange,red
- Government of Canada Action on Climate Change site http://www.climatechange.gc.ca/default.asp?lang=En&n=E18C8F2D-1
- Government of Mexico Ministry of Environment and Natural Resources (SEMARAT) http://www.semarnat.gob.mx/programas/semarnat/Paginas/PECC.aspx
- IPCC, 2018: Summary for Policymakers. In: Global warming of 1.5°C. An IPCC Special Report on the global impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmonotte, P. Zhai, H.O. Portner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufou,a-Okia, C. Pean, R. Pidcock, S. Conners, J.B.R. Matthews,, Y. Chen, X. Zhou,M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.
- Leahy, S., 2017. Earth Will Likely Be Much Warmer in 2100 Than We Anticipated, Scientists Warn. Retrieved from https://motherboard.vice.com/en_us/article/xwvx5q/earth-will-likely-be-much-warmer-in-2100-ipcc-projections
- Levin, K., 2018. Eight (8) Things You Need to Know About the IPCC 1.5°C Report. Retrieved from https://www.wri.org/blog/2018/10/8-things-you-need-to-know-about-ipcc-15-c-report
- Nature, provides a regular synopsis of the latest science through their service "Nature Reports Climate Change" http:// www.nature.com/climate/index.html.
- Plaas, G.N., 1956. The Carbon Dioxide theory of Climate Change, The John Hopkins University, Baltimore, MD, Tellus VIII 2. ScienceDaily, 14 September 2017. Fundaco de Amparo ă Pesquisa do Estado de São Paulo. www.sciencedaily.com/releases/2017/09/170914152226.htm
- Intergovernmental Panel on Climate Change (IPCC). Website: http://ipcc.ch/.
- Cuyahoga County Climate Change Action Plan (CAP 2018) http://www.countyplanning.us/projects/climate-action-plan/
- The Intergovernmental Panel on Climate Change reports, including the Assessment Reports and the more Technical Reports and Special Reports http://www.ipcc.ch/#
- The basics of climate change science are taken from the United States Environmental Protection Agency Climate Change Adaptation Plan, June 2014. Publication Number: EPA 100-K-14-001. www.epa/gov/greeningepa/climate-change-adaptation-plans.
- The United States Global Change Research Program (USGCRP), was used for the Climate Change Impacts on Human Health Plan. https://health2016.globalchange.gov/.
- US Climate Alliance: https://www.usclimatealliance.org/alliance-principles formed 2017
- United States National Oceanic and Atmospheric Administration Climatic Services General: http://www.climate.gov
- USGCRP, 2016. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. Crimmins, A., Balbus, J., Gamble, J.L., Beard, B., Bell, J.E., Doodgen, D., Eisen, R.J., Fann, N., Hawkins, M.D., Herring, S.C., Jantarasami, L., Mills, D.M., Saha, S., Sarafim, M.C. Trtanj, J., and Ziska, L., Eds. U.S. Global Change Research Program, Washington, DC, 312pp. http://dx/doi.org/10.7930/J0R49NQ.

CLIMATE IMPACTS ON HEALTH

How much do you know about climate impacts on human health?

THE IMPORTANCE OF PARTNERSHIPS

Partnerships are vital for the success of the CCCCAP and the mitigation and adaptation strategies identified in this document. The five primary partners include the Cuyahoga County Department of Sustainability, Cuyahoga County Planning Commission, Northeast Ohio Area Wide Coordinating Agency (NOACA), Greater Cleveland Regional Transit Authority (GCRTA), and Cuyahoga County Board of Health (CCBH). Implementing any plan and strategies successfully requires the cooperation of these partner organizations as well as community leaders, local groups and members of the public. Another important consideration affecting human health is land use planning, and the cooperation of the partners engaged with this sector of the CCCCAP.

Photo Credit: BigStock

SIX KEY HUMAN HEALTH IMPACTS FROM CLIMATE CHANGE

Six key areas that will suffer the greatest impacts from climate change are identified, and form the basis of this report. Since extreme weather is an all-encompassing, global influence affecting all aspects of human and ecosystem health, it is presented first:

1. Extreme Weather
2. Food Safety, Nutrition, and Access
3. Vector-Borne Disease and Epidemiology
4. Water Supplies and Waterborne Illnesses
5. Air Quality
6. Mental Health and Well-being

To increase human resilience to the impacts of climate change, a combination of adaptation and mitigation strategies, with recommendations, are presented at the end of each section.

Table 1 lists the six key areas and identifies climate and human health impacts. It also lists the specific populations most affected.

Table 1. Climate Impacts on Human Health in Cuyahoga County		
Climate Impacts	**Human Health Impacts**	**Populations Most Affected**
Extreme Weather		
Extreme Rainfall, Flooding, Erosion, Water Quality	• Deaths from drowning and injuries from flooding • Population displacement, loss of homes and jobs. • Damage to infrastructure; potholes, wastewater treatment plants, potable water and irrigation. • Decrease in water quality and industrial productivity. • Water and food-borne disease from combined sewer overflows.	• Coastal Lake Erie homes • Cuyahoga residents in flood prone areas
Extreme Heat, Resulting Potential for Increased Violence	• Death • Cardiovascular stress and failure. • Heat-related illnesses e.g. heat stroke, heat exhaustion and kidney failure. • Increased injuries from violent acts.	• Diabetics • Those active outdoors • People with respiratory diseases
Increased Average Temperature	• Cardiovascular disease • Increased number and range of Vector-borne disease e.g., Lyme, West Nile, Zika, Malaria. • Increase in Water-borne disease e.g., *E. coli,* cholera. • Increase in Food-borne disease e.g., Salmonella, norovirus, Botulism, hepatitis A and E. • Massive algal blooms producing toxic microcystin polluting Lake Erie. • Allergies caused by pollen and skin • Rashes from poison ivy and stinging nettles. • Possibility of wildfires from forest understory drying out, increased air pollution. • Increase in fungal growth.	• Boaters, bathers, anglers and users of Lake Erie, the Cuyahoga River and other water bodies • Commercial Anglers on Lake Erie • Coast Guard • Allergy Sufferers • Refugees and others who may forage
Food Safety and Nutrition		
Growing Season and Agricultural Changes	• Changing vegetation patterns and crop yields, decreasing food nutrition, increasing prices, food insecurity, hunger and malnutrition. • Increase in arthropod and plant invasive species, decreasing indigenous biodiversity. • Changes in agriculture/forestry leading to unknown consequences to jobs and transportation in our region.	• Urban agricultural workers
Water Supply		
Water-borne Disease, Water Quality, and Droughts	• Food-and water-borne disease. • New and contagious vector-borne diseases. e.g., Dengue Fever, Chikungunya, Ebola • People with kidney, liver and gastrointestinal diseases. • Distribution of food supplies and quality	• Lake Erie and Cuyahoga County River users • Safety net health and social service providers • Food banks
Air Quality		
Poor Air Quality: Air Pollution	• Increased asthma, allergies, cardiovascular and respiratory diseases.	• Allergy sufferers • People with respiratory diseases
Mental Health and Well-being		
Mental Health Distress	• Damage to health care facilities • Damage to homes, infrastructures and buildings. • Increased rate of illness, disease, emergency room use, increased costs borne by employees, health plan, insurance. Companies and residents. • Increase in mental health disorders; depression, anxiety, sense of helplessness, Post Traumatic Stress Disorder (PTSD) and Prolonged Duress Stress Disorder (PDSD, substance abuse. • Disruption, displacement, and migration • Loss of homes, jobs and lives.	• Infants • Children • Individuals in Poverty • Elderly • Hospital Patients • Homeless • Law Enforcement • Emergency Medical Personnel • Outdoor Workers • Those active outdoors • Drug users • PTSD & PDSD sufferers • Mental Health sufferers

Table: Modified from Climate Action for Health: Integrating Public Health into Climate Action Planning, California Department of Public Health, February 2012.

Table Sources: Ohio Department of Health, Centers for Disease Control, The United States Global Change Research Program.

LINKS TO ENVIRONMENTAL RESOURCES THAT HELP COMBAT CLIMATE IMPACTS ON HEALTH

- **Better Health Partnership:**
  http://www.betterhealthpartnership.org/

- **Health Data Matters website has a list of data points that are indicators for human health:**
  https://www.healthdatamatters.org/health-resources

- **OACA Geographic Information Systems Portal:**
  http://www.noaca.org/index.aspx?page=94

- **Urban Poverty Center at Case Western Reserve University Neighborhood Data:**
  http://neocando.case.edu/neighborhood-data-warehouse/

- **The U.S. Environmental Protection Agency's Office of Research and Development and Office of Water's Monthly Webinars:**
  https://www.epa.gov/research/epa-research-webinar-series

- **Cuyahoga County Interactive Mapping Tool and Website details by Community of Land Use, Tree Canopy, and Albedo:**
  http://www.countyplanning.us/projects/cuyahoga-county-greenprint/landcover&treecanopy/

- **ITree; Information and Data to Help With Tree Planting Species, Management, and Costs:**
  https://www.itreetools.org

- **Ohio DRN: Urban Forestry Toolbox The US Forestry Services Tree Atlas:**
  https://usfs.maps.arcigis.com/apps/MapSeries/index.html?appid=96088b1c086a4b39b3a75d0fd97a4c4

- **Vibrant Cities Lab: Urban Forestry Toolkit:**
  https://www.cwp.org/making-urban-trees-count
  https://www.itreetools.org

- **Grass Alternatives: Why & How to Replace Lawns:**
  https://www.healthygreensavvy.com/grass-alternatives/

- **Green Yards and Healthy Homes; the Doan Brook Watershed Partners:**
  https://doanbrookpartnership.org/wp-content/uploads/2019/05/Green-Yards-Healthy-Homes.pdf

- **Cleveland Museum of Natural History's List of Native Plants:**
  https://www.cuyahogaswcd.org/files/assets/cmnhnativeplantlist.pdf

- **Landscaping Solutions from the Chagrin River Watershed Partners:**
  https://crwp.org/index.php/homeowners/landscaping-solutions

- **Sustainable Pest Management from the Xerces Society**
  https://xerces.org/pesticides/

- **Backyard Biodiversity, American Forests:**
  https://www.americanforests.org/magazine/article/backyard-biodiversity/

Ecosystem and human health are directly impacted by the increased frequency and amplitude of all weather events, including micro-bursts and tornadoes. Increased temperatures due to climate change result in more heat and bigger, stronger and more frequent storms, resulting in greater impacts and damage.

Extreme Weather Events

INTRODUCTION

Meteorological and emissions data from the last few decades document an increasing trend in temperatures and the number of days with temperatures exceeding 35°C (95°F). Under maximum emissions without any mitigation, by the Year 2030, projections are for 15 to 20 days a year with temperatures above 35°C (95°F), and by the end of the century, there could be as many as a 115 days with temperatures above 35°C (95°F). (Figure 1, Iverson et al., 2018). From April to July 2020, Northeast Ohio experienced the hottest average daily temperatures recorded over the last 126-year period (www.ncdc.noaa.gov).

The average annual precipitation also shows this same increasing trend. The most recent ten-year average is 42.9 inches (109 cm), most of which still falls in the summer. However, winter is showing the largest precipitation increase of 18.7% over the past ten years. This is due to higher winter temperatures and reduced snowfall, with more moisture available to fall as rain. Climate change is also causing a shift in growing seasons and related plant hardiness zones. The shift locally is away from the lowest minimum temperatures plants can tolerate, to hotter, dryer growing seasons and hardiness zones more akin to mid-Kansas.

Temperature and precipitation trends for Cuyahoga County are provided in the CCCCAP document, with details available on the Cuyahoga County Planning Commission's website (www.countyplanning.us/).

Figure 1. Emissions scenarios showing increasing numbers of days with temperatures greater than 95˚F (35˚C)
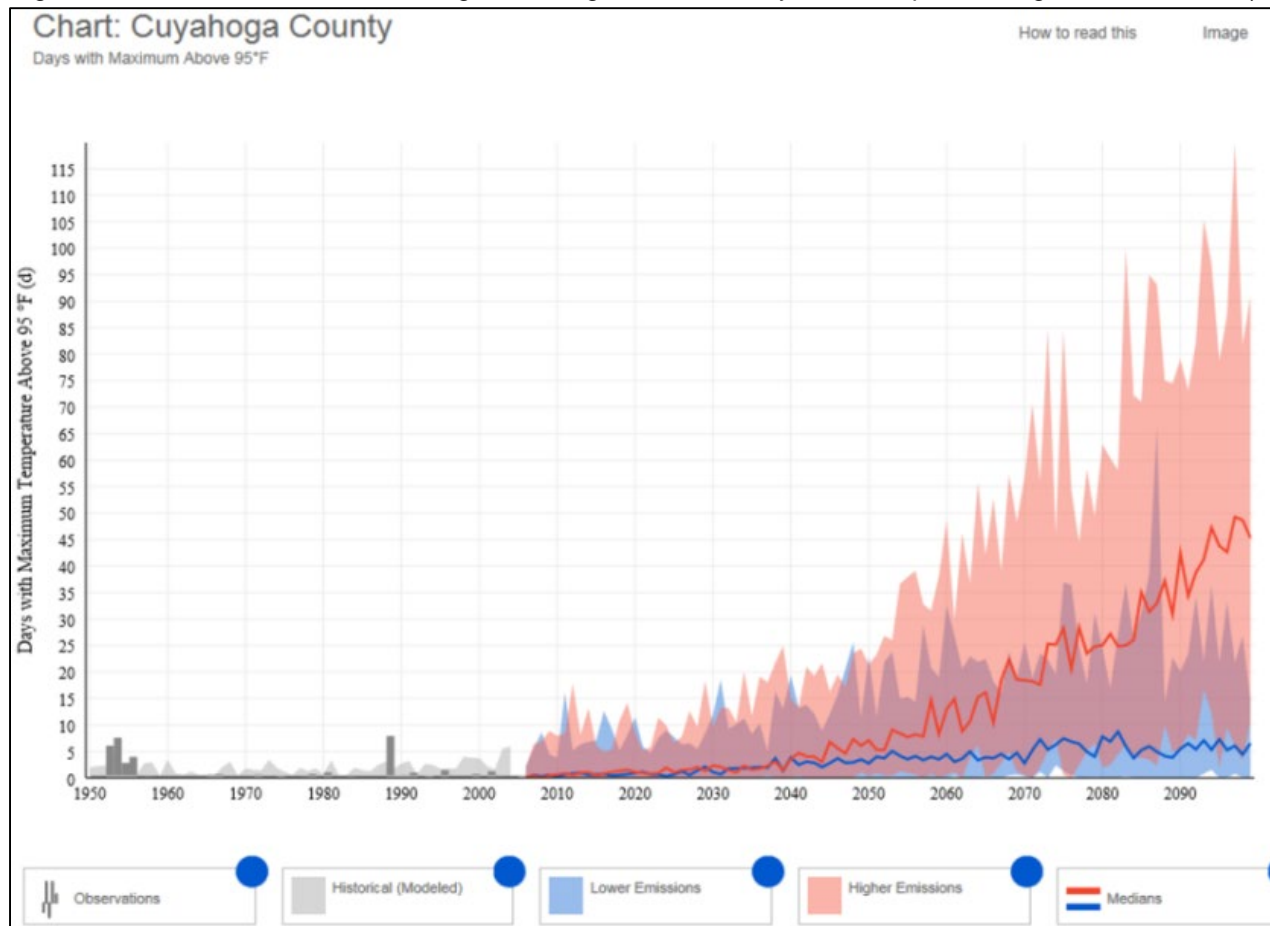

Figure 1. Adapted from Iverson et al., 2018, US Forestry Services, Delaware, Ohio.

EXTREME WEATHER

Extreme weather events in Cuyahoga County, coupled with rising temperatures, are exacerbated by current land use practices. The U.S. Census Bureau Quick Facts estimated that in 2019, Cuyahoga County had a population of 1,248,514.

The majority of this population is concentrated in ecologically transformed urban areas, approximately two-thirds of which are composed largely of impermeable or poorly vegetated surfaces. These areas are susceptible to the heat island effect (cities are hotter than surrounding areas), high levels of ground-level ozone, stormwater flooding, and erosion damage.

Cuyahoga County has seven major land use categories as shown in Figure 2. Mapping of land use is done from aerial surveys and ground-based GIS data, which shows 37% tree canopy cover, 32% grass/shrub cover and the remaining 31% combined road, paved areas, buildings, soil and water surfaces. Figure 2 also shows the highly urbanized, industrialized and fragmented landscape of Cuyahoga, with a scattered, discontinuous tree canopy and grass/shrub cover. The lack of continuous tree canopy does not provide sufficient, unbroken protection for ecologically suitable stormwater retention during periods of heavy rain.

Figure 2 shows grass/shrub land use in light-green, most of which is in the form of lawns. However, ecologically, lawns have limited permeability, and do not significantly reduce stormwater runoff. Rather, they exacerbate nutrient runoff from over application of fertilizers, increased popularity of pesticides and herbicides and subsequent contamination of surface waters. Lawns also require expensive, ongoing maintenance including the use of lawnmowers, which adds more CO_2 to the already high level of emissions in the County.

Tree cover comprises 37% of the land in Cuyahoga County. This total includes all individual street trees, exotic species and other isolated plantings which provide limited ecosystem benefits. Single trees are subject to heat, water and temperature stress and do not provide protection for soils, moisture absorption or a significant reduction in ambient temperatures. Additionally, a significant number of these single trees are mature, with no young trees growing to replace mature ones when they die. Biodiversity is also reduced, limiting genetic availability and as a result, reduced resilience to climate change, insect attack and other, invasive arthropod pests and biological pathogens.

Approximately 32% of Cuyahoga County land use consists of impervious surfaces and is divided as follows; 9% for buildings, 7% roads, 14% other hard, paved areas, with the remaining 2% divided equally between bare soil and terrestrial water-systems (Lake Erie is excluded). The CCCCAP document has an interactive map and site which provides details of land use, tree canopy cover and albedo (the proportion of light or radiation reflected by a surface) by suburb, township, and community. More information on environmental planning and land use locally is available at Environmental Archives – Cuyahoga County Planning Commission.

Maximum ecosystem function and biodiversity is found in continuous forest stands (Iverson et al., 2018). The minimum size forest stand varies depending on species composition, precipitation and soil conditions (Iverson et al., 2018). In Cuyahoga County, a much smaller percentage of land-cover is actually composed of stands of continuous tree canopy. These provide benefits of storm water retention, carbon sequestration, lowering the heat-island effect, limiting ground-level ozone, and providing shade and protection. Trees assist with human health benefits, ecosystem function, and biodiversity protection. Most of the remaining continuous forest cover forms most of the 22,000 acres of the Cleveland Metroparks system.

Figure 2. The seven major categories of land use in a portion of Cuyahoga County between Interstate 480 West and Interstate 77 South

Figure 2 derived from the Cuyahoga County Planning Commission and presented in the CCCCAP document showing percentages of Cuyahoga County land use.

In Cuyahoga County, land used for agricultural purposes includes only 1,984 acres. However, in Ohio, some 14 million acres are farmed, making agriculture a major source contributing to climate change and global warming. Industrial farming methods transform landscapes and add millions of ruminants to the planet annually. Farming adds Greenhouse Gas (GHG) emissions through plowing, fertilizing and the raising of farm animals. Plowing transforms grasslands or forests to farm fields. This process releases CO_2 previously held in soils. Fertilizers decompose and release Nitrous Oxide (NO_2). Herbivores, including cattle, sheep, goats, and other ruminants, release Methane (NH_4) as part of their digestive process. Carbon Dioxide, Nitrous Oxide and Methane are all powerful Greenhouse Gas (GHG). Methane absorbs four times more infrared radiation than CO_2, while Nitrous Oxide absorbs 300 times more infrared radiation than CO_2.

EXTREME HEAT

Extreme heat poses a greater threat than extreme cold to human and ecosystem health (USGCRP 2016). The temperature at which extreme heat starts to become a human health concern occurs at the average human body temperature of 37°C (98.6°F). Beyond this temperature, the human body cannot cool efficiently, which in extreme cases, may result in death. The tragedy is that in many cases heat-related deaths are preventable. To help combat this, cities can implement proactive severe heat response plans (Kiser et al., 1999).

The high daytime temperatures are often followed by increasing hotter nights, due to the heat island effect. This results in cities that do not cool down as much as surrounding rural areas. This can leave cities as much as 12.2°C (22°F) hotter after sunset (http://www.epa.gov/heat-islands/heat-island-impacts). In Cleveland, National Weather Service records (NOAA, Nationally Weather Service, Cleveland Hopkins Airport, Ohio) for 2018 show that evenings were the hottest on record since temperatures were first recorded in 1938. The average low was18.6°C (65.6°F) [Rich Exner, www.cleveland.com, August 13th 2018]. The effects of increased, hotter nights can result in conditions that make it nearly uninhabitable in metropolitan areas for people without air conditioning (Sherwood and Huber, 2010). The study by Sherwood and Huber (2010) also indicated that the process of maintaining a suitable human body temperature at 37°C (98.6°F) would require significant increase in the use of air conditioners, resulting in an increase in the consumption of electrical power and CO_2 emissions. This would leave vulnerable groups, especially urban socioeconomically disadvantaged, at even greater risk.

Photo Credit BigStock

Extreme Heat and Increased Violence

Studies throughout the U.S. (Envisage Technologies 2014; Anderson and Bell, 2011; Rotten, 2014) have documented increasing evidence that links rising temperatures to increased levels of violent crime (Ranson, 2014; Schinasi and Harma, 2017). This data indicates that as daily temperatures continue to rise due to climate change, violent crime will also continue to follow this pattern. Climate change is projected to generate an additional 22,000 murders, 102 million aggravated assaults, 260,000 robberies and 180,000 cases of rape between 2010 and 2099. The 2010 study by Burke and Sheridan showed the link between the effects of extreme heat, and increased violence in the City of Cleveland, between 1999 and 2004. Their study found figures for violent crime of 1,102 per 100,000 people compared with the national average of 497 per 100,000, and that for Cleveland, there is "an absolute increase in crime during hotter conditions" (Butke and Sheridan 2010, pp 135).

Weekends and nights have higher mean counts of aggressive crime, which is exacerbated by alcohol consumption. There are several main theories linking heat and violence, all of which show an increase in feelings of irritation, annoyance, and discomfort resulting in aggression and crime. Butke and Sheridan's definition of violent crime included domestic violence assault, non-aggravated assault, aggravated assault, robbery, rape and homicide.

Climate Change Indicators and Heat-related Illness and Deaths

Extreme heat affects human health by causing heat cramps, heat exhaustion, heat-stroke, and potentially even death. In the U.S., 9,000 people died from heat-related causes between 1979 and 2014 (CDC, 2016; Sarofile et al., 2016; USGCRP, 2016.) The number of deaths increased in the years where heat-waves were recorded, with more heat-related deaths in cities than rural areas (Medina-Ramon and Schwartz, 2007; Melilo et al., 2014.) During the 1999 heat-wave, 18 residents of Cincinnati, Ohio died between July 12th to August 10th, when the heat index peaked at 41.6°C and 46.1°C (106.9°F– 114.98°F), respectively (Kaiser et al., 2001, 2007). In Chicago, Illinois between July 11th and July 27th 1995, 465 heat-related deaths were recorded on death certificates (CDC, 1995).

People with chronic health conditions are more susceptible to heat-related ailments. Socio-economic factors, such as low income and unemployment, may also make impacted populations more vulnerable. For extreme heat evens with temperatures over 35°C (95°F), the most vulnerable populations include the elderly (Zanobettiet al., 2012), young children, those with mental health conditions, outdoor workers, those without air conditioning, and the socially isolated (Sarofimet al., 2016). Factors of social equity will predicate where human health issues will be more severe and thus require more facilities, staff, and implementation and management of mitigation and adaptation strategies.

Details regarding the effects of climate change indicators and resulting heat-related deaths can be found in the US EPA document: https://www.epa.gov/climate-indicators/climate-change-indicators-hear-related-deaths.

Urban Heat Island Effect

The heat island effect is defined in the Merriam-Webster Dictionary as "an urban area in which significantly more heat is absorbed and retained than in surrounding areas". It is the result of industrial development and is a unique phenomenon identified in high-rise, metropolitan areas; the mega-cities and similar built-environments. The effect is due to the large areas of impervious, dark or black surfaces, e.g. roads, parking lots, and rooftops, which absorb solar

Buildings show in red are the hottest (66.56 F = 19.3°C), with blue at the coolest temperatures (40.46 ˚F= 4.7°C).

radiation and hold heat. In some cases, this heat is retained and is not dissipated at night. Consequently, cities may have higher daytime temperatures of 1° C to 3°C (1.8°F to 5.4°F) than surrounding urban or rural areas (https://www.epa.gov/heat-islands/heat-island-newsroom). At night, cities do not cool off as rapidly as rural areas, resulting in elevated temperature and exacerbating the human health risk after dark.

By contrast, white or light surfaces reflect solar radiation allowing for cooling. Albedo is the measurement of the reflection of solar radiation from a surface and is measured on a scale from 0 to 1, with 0 representing total absorption and 1 representing complete reflection. Newly laid black, tarred road surfaces, have an albedo of 0.04, indicating almost total absorption of infrared radiation. Older roads, driveways, and gray concrete surfaces have an albedo from 0.04 to 0.12 (Pon B, 1999). White surfaces, clouds and snow in particular, are the best reflector of solar radiation, with an albedo for fresh snow of 0.85, indicating an almost complete refection of infrared radiation.

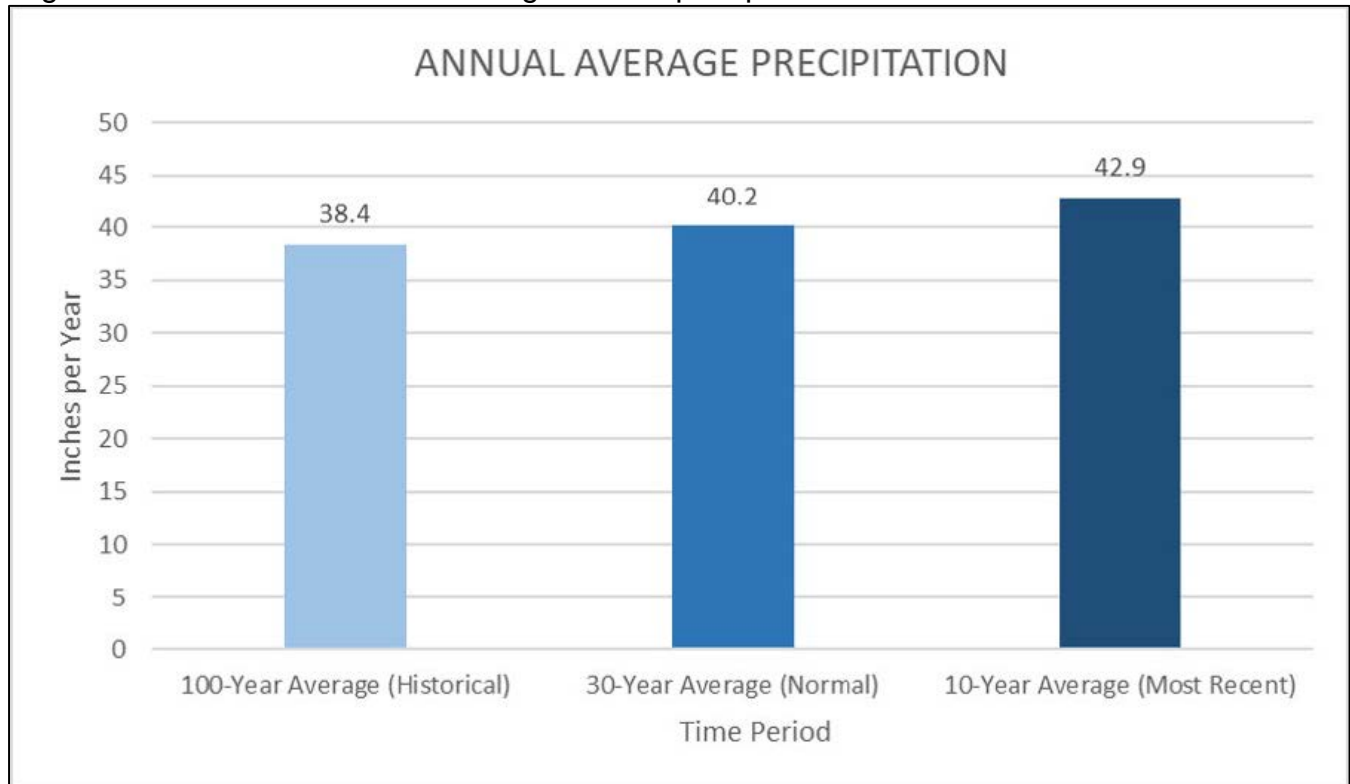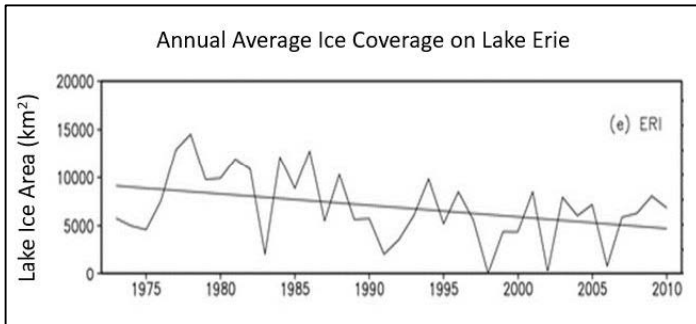Figure 3. Illustration of the increasing trend for precipitation over three different scenarios

ANNUAL AVERAGE PRECIPITATION

Figure 3 data was derived by the Midwestern Regional Climate Science Center and presented in CCCCAP 2018.

INCREASED PRECIPITATION

Total precipitation in Cuyahoga County during 2017 was 55 inches (139.7 mm), with projections of 65 inches (165.1 mm) possible by the mid-2060s (CCCCAP, 2018). Precipitation projections identify a steady increase over the next ten years, with the average of 42.9 inches (109mm) falling per year. A total of 11.9 inches (30.3mm) will typically fall in summer; however, the greatest seasonal increase in precipitation will occur in winter, and may equal 8.9 inches (22.6mm), an increase of 18.7%.

The number of extreme rain-days (defined as over an inch of rain per day), will also increase. Predictions for the next ten years show a 6.1% increase, for 30 years an increase of 16.6% and for 100 years a 26.2% increase (CCCCAP, 2018). The frequency and intensity of extreme rain-days will also increase storm frequency and intensity, which will exacerbate flooding events in the community.

Figure 4. Decreasing trend of ice cover for Lake Erie since the early 1970s.

A satellite view of the Great Lakes in January, 2005, showing ice buildup and snow cover. Photo Credit: Terra MODIS.

Decrease in Ice Cover

Between 1975 and 2010, there has been a steady decline in Great Lakes ice cover (CCCCAP, 2018). During the same time, ice cover for Lake Erie has decreased by 50%, with an overall reduction of 71% for all five Great Lakes. This decreasing winter ice-cover allows for more moisture available to fall as rain or snow in winter partially explaining the higher percentage of precipitation occurring during the winter months.

The effects of decreased ice cover on human health will be both direct and indirect. With less ice cover and thus fewer freezing days, deaths due to hypothermia and frostbite injury may decrease. However, numerous parasites, invasive plant, and animal species will not be controlled by lengthy freezing periods, allowing for increased numbers and the potential worsening of arthropod-borne diseases and allergens. The secondary and arguably more ecologically important consequence of reduced ice-cover is the lowering of the albedo by exposing more dark earth. The dark earth absorbs more radiation, adding to global warming. Ice and snow, having a high albedo (0.85) which reflects infrared radiation, helps to reduce the Greenhouse Effect.

Increase in Climate Refugees

Current global trends suggest immigration to the United States will increase from areas experiencing long-term, climate induced drought, land use change, desertification, food shortages, and war. The internal displacement of U.S. residents will also increase as the population moves from areas experiencing increased climate change effects to more resilient areas. The Great Lakes Region will be particularly susceptible as it holds a fifth (20%) of the world's freshwater, which will be increasingly sought after by agriculture, manufacturing and as drinking water outside of the Great Lakes Watershed.

Great Lakes Ice Coverage Decline 1973-2010	
All Great Lakes	71%
Lake Ontario	88%
Lake Superior	79%
Lake Michigan	77%
Lake Huron	62%
Lake Erie	50%
Lake St. Clair	37%

This table shows the widespread decline of ice and snow cover over all of the Great Lakes.

Albedo in Latin means "whiteness." Painting houses, roofs, or other dark surfaces white reduces absorbed infrared radiation and helps to reduce the impacts of climate change.

MITIGATION AND ADAPTATION STRATEGIES

Trees Can Make a Difference

Rising temperatures due to extreme CO_2 levels and the resulting extreme weather events, can be slowed with the implementation of mitigation techniques. One powerful mitigation technique that has been proposed is the planting of trees and establishment of larger tree canopy. Increasing tree coverage will help build resilience against extreme weather events by lowering the local temperature, reducing albedo along with the heat island effect, and improving storm water retention and water quality. Both the City of Cleveland and surrounding Cuyahoga County are committed to further develop forest canopies. On Arbor Day 2017, the City of Cleveland and partners vowed to plant well over 300,000 trees in the upcoming few decades to achieve a 21% increase in tree coverage. The Cuyahoga County Planning Commission completed an Urban Tree Canopy Assessment; a detailed study of the land availability for the use and benefits of planting trees. This specific information will help guide communities and individual property owners as they look to expand tree coverage.

Keeping Crime in Check

To help minimize the potential for elevated levels of crime and the number of residents susceptible to excessive heat-days, the benefits of an excessive heat alert system are currently being evaluated. This type of system would allow meteorological agencies to inform law enforcement agencies and associated increased humidity and temperature levels are projected to go above 35°C (95°F); alerting them to be on a heightened state of vigilance. Law enforcement and EMS would be warned to potentially expect an increase in random, violent crime due to rising agitation brought on by extreme heat.

Cut Out the Red Meat

Lowering consumption levels of red meat can also potentially serve as an impactful climate mitigation strategy. Some experts emphasize the impact meat production has on emissions of Greenhouse Gasses (GHG). Richard Waite and his fellow researchers at the World Resources Institute emphasize the point that *"Beef requires 20 times more land and emits 20 times more GHG emissions per gram of protein than common plant proteins"* (Waite et al., 2019).

A 2018 study published in the Proceedings of the National Academy of Sciences of the United States of America by Bar-Ona et al., found that 60% of mammals on earth are livestock, 36% are humans, while the remaining 4% are wildlife (Bar-Ona, et al., 2018). The majority of livestock are cows, which produce methane from burping while chewing their cud. Methane is about 30% more powerful than CO_2 as a greenhouse gas. Reducing the amount of red meat eaten by as little as one meal per week would help reduce overall methane emissions. Eating excessive quantities of red meat is not only unhealthy from an environmental perspective, but also from a heath perspective, with well-documented adverse health effects. It is also more costly to eat red meat than plant proteins.

A cow produces approximately 220 pounds of methane a year. If you extend this estimation to the approximate 1 billion cows on earth, that equals approximately 220 trillion pounds of methane released to the atmosphere annually.

Concrete and Construction

Another potential mitigation technique concerns the production of cement, which emits large amounts of CO_2. Zeolite powder and Zeolite sand makes CO_2 absorbing concrete (More et al., 2014), which in turn enables impermeable surfaces to serve an ecological function. This CO_2 absorbing concrete would have the advantage of removing atmospheric CO_2, which could help lower ambient temperature.

REFERENCES

Extreme Weather

- Butke., and Sheridan S.S., 2010. An analysis of the Relationship between Weather and Aggressive Crime in Cleveland, Ohio. Weather, Climate and Society, Vol 2, pp. 127-139
- Envisage Technologies 'Climate and crime: How temperature change could impact future law enforcement. www.envisagenow.com/climate-and-crime, 20 August 2014.
- Ranson, M., 2014. Crime, weather and climate change, Journal of Environmental Economics and Management, accessed via Envisage Technologies 'Climate and crime: How temperature change could impact future law enforcement. www.envisagenow.com/climate-and-crime, 20 August 2014.
- Sherwood, S.C., and Huber, M., 2010. An adaptability limit to climate change due to heat stress. Proceedings of the National Academy of Sciences 107: 9552-9555. www.pnas.org/cgi/10.1073/pnas.0913352107
- Schinasi, L.H., and Hamra, G.B., 2017. Time Series Analysis of Associations between Daily Temperature and Crime Events in Philadelphia, Pennsylvania. J., Urban Health. 94(6):892-900. doi: 10.1007/s11524-017-0181-y.

Heat Related Deaths

- Anderson, G.B., and Bell, M.L., 2011. Heat waves in the United States: Mortality risk during heat waves and effect modification by heat wave characteristics in 43 U.S. communities. Enviorn. Health Persp. 119(2) pp. 210-218.
- Berko, J., Ingram, D.+D., Saha, S., and Parker, J.D., 2014. Deaths attributed to heat, cold and other weather events in the United States, 2006-2010. National Health Statistics Reports, Numbers 76. National Center for Health Statistics. www.cdc.gov/nchs/data/nhsr/nhsr076.pdf.
- CDC (U.S. Centers for Disease Control and Prevention), 2016. Indicator: Heat-related mortality. National Center for Health Statistics. Annual national totals provided by National Center for Environmental Health staff in June 2016. http://ephtracking.cdc.gov/showIndicatorPages.action
- CDC (U.S. Centers for Disease Control and Prevention), 2016. CDC WONDER database: Multiple cause of death file. Accessed July 2016. http://wonder.cdc.gov/mcd-icd10.html
- CDC (U.S. Centers for Disease Control and Prevention), 1995. Heat-related mortality– Chicago, July 1995. Morbidity and Mortality Weekly Report 44(31) pp. 577-579.
- Kaiser, R., Rubin, C.H., Henderson, A.K., Wolfe, M.I., Kieszak, S., Parrott, C.L., and Adcock, M., 2001. Heat-Related Death and Mental Illness During the 1999 Cincinnati Heat Wave. The American Journal of Forensic Medicine and Pathology 22(3), pp. 303-307, Lippincott Williams & Wilkins, Inc., Philadelphia.

- Kaiser, R., Le Tertre, A., Schwartz, J., Gotway, C.A., Daley, W.R., and Rubin, C.H., 2007. The effect of the 1995 heat wave in Chicago on all-cause and cause-specific mortality. Am. J. Public Health 97 (Supplement 1), S158-S162.
- Medina-Ramon, M., and Schwartz, J., 2007. Temperature, temperature extremes, and mortality: A study of acclimation and effect modification in 50 U.S. cities. Occup. Enviorn. Med. 64(12), pp. 827-833.
- Melillo, J.M., Richmond, T.C., and Yohe G.W., (eds.)., 2014. Climate change impacts in the United States: The third National Climate Assessment. U.S. Global Change Research Program. http://nca2014.globalchange.gov
- More, B., Jadhav P., Jadhav, V., Narule, G., and Mulani, S., 2014. CO_2 Absorbing Concrete Block, International
- OAA (National Oceanic and Atmospheric Administration), 2012. National Centers for Environmental Information. www.ncdc.noaa.gov.
- Sarofilm, M.C., Saha, S., Hawkins, M.D., Mills, D.M., Hess, J., Horton, R., Kinney, P., Schwartz, J., and St. Juliana, A., 2016. In: Chapter 2: Temperature-related death and Illness. The impacts of climate change on human health in the United States: A scientific assessment. U.S. Global Change Research Program. https://health2016.globalchange.gov.
- USGCRP, 2016. The impacts of Climate Change on Human Health in the United States: A Scientific Assessment. Crimmins, A., Balbus, J., Gamble, J.L., Beard, C.B., Bell, J.E., Dodgen, D., Eisen, R.J., Fann, N., Hawkins, M.D., Herring, S.C., Jantarasami, L., Mills, D.M., Saha, S., Sarofim, M.C., Trtanj, J., and Ziska, L., Eds. U.S. Global Change Research Program, Washington, DC, 312pp. http://dx.doi.org/10.7930/J0R49NQX
- Weisskopf, M.G., Anderson, H.A., Foldy, S., Hanrahan, L.P., Blair, K., Torok, T.J., and Rumm, P.D., 2002. Heat wave morbidity and mortality, Milwaukee, Wis., 1999 vs 1995: An improved response? Am.. J. Public Health 92 pp. 830-833.
- Zanibetti, A., O'Neill, M.S., Gronlund, C.J., and J.D. Schwartz, 2012. Summer temperature variability and long-term survival among elderly people with chronic disease. P Natl. Acad. Sci. USA 109(17) pp. 6608-6613.

Mitigation and Adaptation Strategies

- Bar-Ona, Y.M., Phillipsb, R., and Miloa, R., 2018. The biomass distribution on Earth. PNAS, vol. 115, no 25. wwwnpnas.org/content/suppl/2018/07/13/1711842115.DC1
- Waite R., Searchinger T., and Ranganathan J., 2019. 6 Pressing Questions About Beef and Climate Change, Answered. Published on World Resources Institute (https//www.wri.org). Source URL: https://wwwwri.org/blog/2019/04/6-pressing

Food is not medicine, however, eating a diverse diet of plant proteins, nuts and vegetables promotes health and reduces the chance of contracting diseases.

Food Safety, Nutrition, and Access

INTRODUCTION

Statewide, Ohio farms approximately 14 million acres. Cuyahoga County, which is highly urbanized, farms only 1,984 acres (CCCCAP, 2018). Consequently, the effects of climate change on Cuyahoga County commercial agricultural will be minimal. However, the effects of climate change related to food security, limited access to food, decreased nutritional quality of food, and increase prices will affect County residents. The following section, adapted from the U.S. Global Climate Change Research Program, lists four key findings linking climate change and food. These categories include:

- Food-borne illness, food safety, nutrition and distribution.
- Chemical contamination in the food chain.
- Nutritional value of food lowered by rising Carbon Dioxide levels.
- Extreme weather limiting access to safe food.

The distribution and availability of healthy foods are limited for people residing in "food deserts." In Cuyahoga County, these "food deserts" have been identified using County GIS vulnerability mapping techniques and are incorporated in the vulnerability index for the County (CCCCAP, 2018). As climate change exacerbates food insecurity, CCBH is engaged with stakeholders to establish supermarkets and other sources of fresh and nutritious food for the residents in these areas.

FOOD-BORNE ILLNESS, FOOD SAFETY, NUTRICIAN, AND DISTRIBUTION

The relationship between climate change and the effects on human health is complex. Indirect health effects include drinking contaminated water, food-borne and vector-borne diseases, and zoonosis – the transmission of disease-causing pathogens from non-human animals to humans. As early as 2012, it was estimated that climate change associated diseases were steadily increasing and comprised 4.6% of all environmental risks in the U.S. (Kendrovski and Gjorgjev, 2012). Many of the pathogens that cause disease are thermophilic, meaning they thrive in warmer temperatures.

As the average global temperature continues to increase, so does the potential for accelerated pathogen growth. The most common pathogens associated with food-borne illness are norovirus and Salmonella. Other pathogens responsible for gastrointestinal food-borne diseases and health effects, including diarrhea and vomiting, are *E. Coli*, Campylobacter, Hepatitis A and Listeria.

Federal, state and local health agencies maintain robust food safety programs that focus on inspection of facilities and food storage, handling and preparation techniques. Local health departments, including CCBH, conduct food safety training to educate those who work in the food industry. They are also tasked with investigating reported food-borne illnesses outbreaks. Health departments also maintain protocols so they are prepared to respond to public health concerns associated with disease causing pathogens like Ebola, West Nile, and Zika virus.

CHEMICAL CONTAMINATION IN THE FOOD CHAIN

Elevated sea surface temperatures will lead to greater accumulation of mercury in seafood. Increases in the frequency and extent of extreme weather events will introduce contaminants info the food chain. Rising carbon dioxide concentrations will alter incidence and distribution of pests, parasites, and microbes, leading to an increased use of pesticides and veterinary drugs (USGCRP, 2016). Rising temperatures will increase extraction of volatile chemicals, mainly phthalates, from plastics, thus contaminating freshwater. Polychlorinated biphenyls (PCBs), now found in all freshwater, are linked to increased cases of cancer, endocrine disruption, and mutagenic diseases (Tickner et al., 2001, Lovekamp-Swan 2003, Gross 2017, Lanphear 2017).

RISING CARBON DIOXIDE LEVELS

Rising CO_2 leads to the reduction of mineral nutritional components in plants (Loladze, 2014). Reduced mineral nutritional concentrations in crops and wild plants will have a direct negative impact on human and non-human animal health (McGrath and Lobell, 2013). This will be significant for imported crops such as rice and wheat, which will have reduced protein and essential minerals due to rising atmospheric levels of CO_2.

EXTREME WEATHER LIMITS ACCESS TO SAFE FOOD

Increasing extreme weather events, such as flooding, tornadoes, and hurricanes, will be a disruptive force affecting the current trucking and railroad logistical infrastructure and food distribution warehousing system. As a result, we will see the potential for increased food spoilage caused by bacterial contamination of foods requiring refrigeration. In turn, this would exacerbate the availability of nutritional foods, and equitable distribution and access, which are already lacking in vulnerable communities.

MITIGATION AND ADAPTATION

Supporting urban agriculture (urban farms, community gardens, indoor gardens, aquaculture) and locally grown foods can have a direct impact on the potential reduction of emissions related to the transportation of food products into Cuyahoga County. Additionally, locally grown foods typically have a higher nutritional quality, as opposed to industrial scale agricultural and mass produced foods. Industrially produced foods are often deficient in micronutrients, essential minerals, vitamins, and trace elements. Urban agriculture also increases local resilience from the impacts of extreme weather. It reduces dependence on overseas imports and local imports from drought-prone regions of the U.S. Continued monitoring and inspection of all restaurants and food operations, along with enhanced food defense practices (protecting food from acts of intentional adulteration) will help reduce the potential For food-borne disease outbreaks.

Converting large tracts of land to agriculture decreases indigenous soil microbe biodiversity, degrades soils texture, reduces fertility and produces increased levels of emissions. It also adds to climate change by potentially putting more methane and CO_2 into the air. Overused fertilizers – phosphate, ammonium and nitrates - wash off land and pollute waters, provide nutrients for harmful algal blooms and decrease water quality. No-till agriculture has proven to be an alternative to industrial-scale farming with fewer negative effects.

References

- Chapter 7, in: Structure and Function of Food Engineering. Downloaded from: http://www.intechopen.com/books/structure-and-function-of-foodengineering
- Loladze, I., 2014. Hidden shift of the ionome of plants exposed to elevated CO_2 depletes minerals at the base of human nutrition. — Elife pp 1-29.
- Lourenco-de-Oliveira R, and Failloux A-B, 2017. Lessons learned on Zika virus vectors. PLoS Negl Trop Dis 11(6): e0005511. https://doi.org/10.1371/journal.pntd.0005511
- Maffini, M.V., Nelter, T.G., and Vogel, S., 2017. We are what we eat: Regulatory gaps in the United States that put our health at risk. PLoS Biol 15(12): e2003578. https://doi.org/101371/journal.pbio.2003578
- McGrath, J. M., and Lobell, D.B., 2013. Reduction of transpiration and altered nutrient allocation contribute to nutrient decline of crops grown in elevated CO_2 concentrations. — Plant, Cell Environ. 36, pp. 697-705

Vector-Borne Diseases and Epidemiology

INTRODUCTION

Climate change is lengthening the seasonal growing period, while also altering geographic conditions, to allow for the spread of invasive and alien species of plants and animals. These factors will alter the range of vectors and vector-borne diseases (USDGCR 2016; Iverson et al., 2018). These vectors include mosquitoes, ticks, fleas, and other insects or organisms that can potentially transmit diseases. To date, the United States has fourteen vector-borne diseases, which all contribute to a major national health concern. Six of these diseases are spread by ticks, seven by mosquito and one, the Plague, by

fleas (US Global Research Program, Chapter 5). Diseases spread by ticks are an increasing concern in Ohio and have been reported to the Ohio Department of Health (ODH) more frequently in the past decade, with Lyme disease and Rocky Mountain Spotted Fever (RMSF) being the most common. The number of cases of other tick-borne diseases, such as anaplasmosis, babesiosis, and ehrlichiosis, are also on the rise.

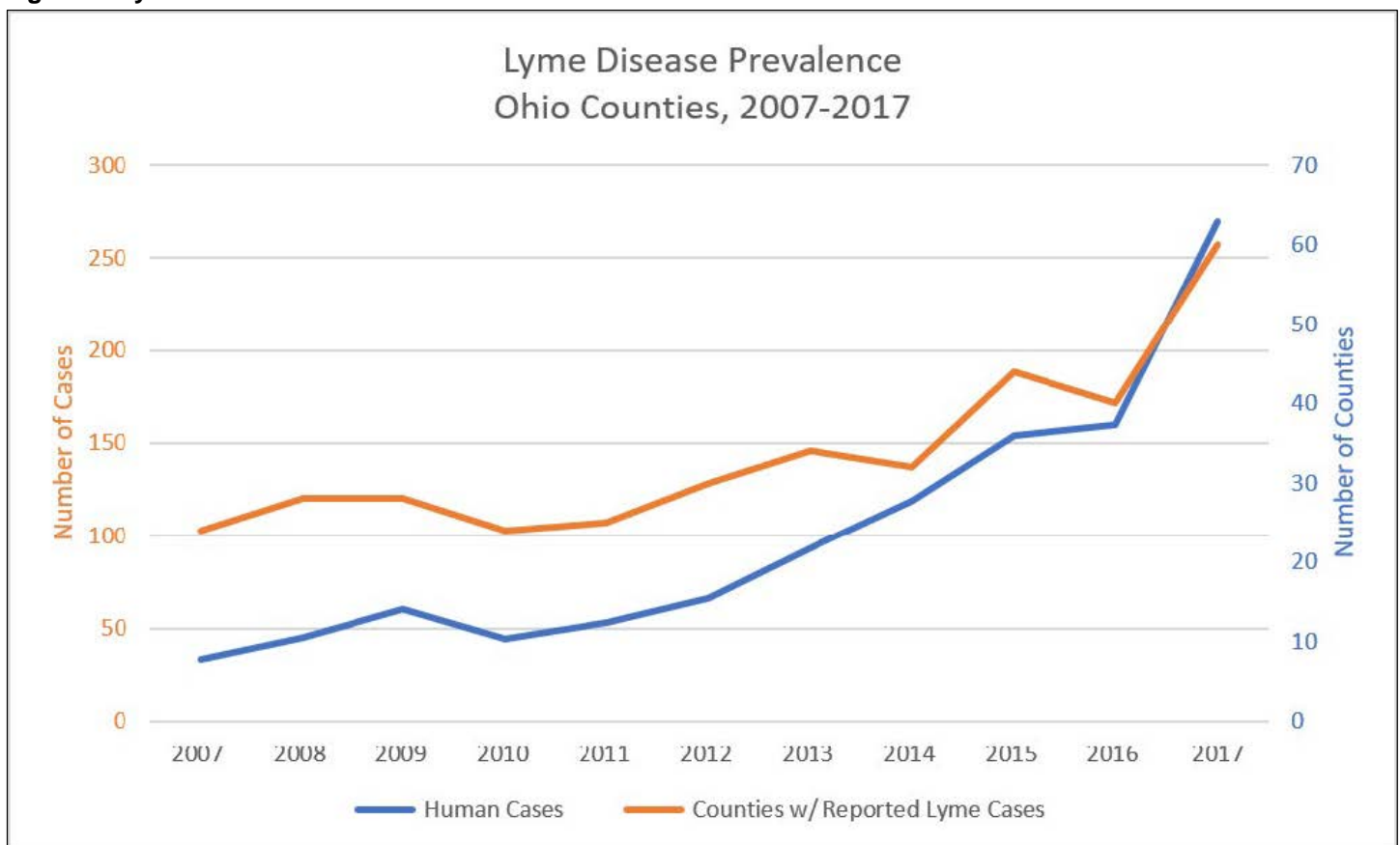**Figure 5. Lyme disease increase in humans in Ohio counties from 2007-2017**

Figure 5 is modified and updated from the Ohio Department of Health, 2017/2018 data.

LYME DISEASE

The Blacklegged or Deer Tick (*Ixodes scapularis*), is the arthropod host which spreads Lyme disease. Climate change related variables, such as increased

temperature and rainfall, will help determine the tick's geographic distribution and seasonal pattern of activity. As illustrated in Figure 5, there has been a

steady increase in the number of Lyme disease cases and the range of the disease. Lyme disease is essentially becoming more common and widespread in Ohio.

Many publications and internet sites, including the Cuyahoga County Board of Health's website (www.ccbh.net), provide guidance on reducing exposure to ticks and what to do if ticks are found on humans, dogs or other pets. These sites also provide a number of valuable vector-related resources and information.

The potential for contracting Lyme disease is based on a complex interaction of three factors - tick population density, prevalence of infected ticks and frequency of human contact with infected ticks. It is important to remember that being bitten by a tick does not necessarily mean you have been infected.

Photo Credit: Bigstock

The Blacklegged or deer tick (*Ixodes scapularis*) is responsible for spreading Lyme disease.

ARTHROPOD VECTOR CONTROL

The mosquito species primarily responsible for spreading viral diseases include Anopheles, Culex, and Aedes (including *Aedes aegypti* and *Aedes albopictus).* Mosquito surveillance for these and other mosquitoes is routinely conducted as part of local vector control programs, like the one conducted by CCBH. Trapped mosquitoes are collected and sent to the Ohio Department of Health (ODH) laboratory for identification and disease testing.

Local mosquito control programs help reduce exposure to mosquitoes by treating mosquito breeding sites in a manner that prevents mosquito larvae from ever maturing into adult mosquitoes.

Health departments also provide public education that property owners can use to help eliminate suitable mosquito habitats. Education also includes guidance on personal protection, including wearing long sleeved shirts, long pants, and using repellants, which can reduce exposure to mosquitoes and ticks.

West Nile Virus (WNV), is transmitted by several species of mosquitoes. The Ohio Department of Health (ODH) has tracked human, mosquito and veterinary cases of West Nile Virus infection since 2001, when the virus was first detected in Ohio. Since that time, Ohio has averaged 58 cases per year. However, epidemics can flare up under certain environmental conditions in the summer and early fall. In 2002, the state recorded a total of 441 cases and 31 deaths attributed to WNV.

Zika virus is transmitted by the yellow fever mosquito, *Aedes aegypti,* which is found in the tropics and southern United States. This mosquito is not known to be established in Ohio, however, in 2016, 95 Ohioans became infected while traveling in areas where Zika virus is found. The Asian tiger mosquito, *Aedes albopicus,* is a related mosquito species. It is found in Ohio and could potentially transmit Zika Virus, although it has not been documented to show a role in the transmission of human cases in the U.S.

Photo Credit: Bigstock

A female Aedes albopictus mosquito with its' characteristic white and black stripped markings, engorged with a blood meal from a human host.

Rising temperatures may allow for these mosquito species to become more relevant in Ohio. Climate change increases day and night temperatures, lengthens spring and summer seasons, and extends the number of hot days with temperatures above

32°C (90°F) (Iverson et al., 2018). Tires, plastic bags, cups, bottles, metal cans and even cemetery vases once filled with rainwater; provide ideal urban, breeding sites for diseasing-spreading mosquitoes. Birdbaths, blocked gutters and unused pool covers are also potential breeding sites.

In Ohio, and Cuyahoga County specifically, the most significant mosquito-borne diseases are Eastern equine encephalitis virus, La Crosse virus, St. Louis encephalitis virus and West Nile Virus (ODH, 2018).

TRAVEL-RELATED TROPICAL DISEASES

With increased travel for both civilians and military personnel to tropical and subtropical countries, an increase of infectious, tropical diseases can be expected. In Ohio, travel-related topical diseases, including Chikungunya, Zika virus, Malaria, and Dengue Fever have been reported. Dengue Fever is now found in 125 countries and is regarded as the most wide-spread global disease (ODH, 2017, 2018). Details for all these statistics and trends can be found at http://www.odh.ohio.gov/zdp.

ARTHROPOD AND REPTILE BITES

Climate change may provide extended ranges for venomous arthropods, such as spiders, centipedes, bees, wasps, and ants. This will potentially increase contact with humans and thus the frequency of bites. Bite severity is determined by:

- Animal species;
- Quantity and category of venom (haemo, neuro or cytotoxic)
- Location of and number of bites;
- Victim's age, body mass, and physical condition.

In extreme cases, the onset of anaphylactic shock can be rapid and fatal.

Increased numbers of days with warmer temperatures, coupled with milder winter temperatures, may open up new habitat and range for venomous reptiles, including snakes. In 2018, a case of a Copperhead snakebite cost the 9-year-old Indiana victim's parents $67,957 for 4 vials of antivenin, and a total bill of $142,938 in health care costs (Keiser Health News, reported by Carmen Heredia Rodrigues April 30, 2019).

MANAGEMENT AND ADAPTION

Ohio's Mosquito-borne Disease Surveillance program incorporates the monitoring, trapping, identification, and testing of mosquitoes, including those from the genus *Aedes,* which is the vector for West Nile Virus, Zika and the Rift Valley Fever. Comprehensive mosquito control programs at the state and local level help provide data for field and health care staff to act swiftly should it be necessary. In addition, a variety of educational materials are provided for the public on websites, including the Centers for Disease Control and Prevention (www.cdc.gov), the Cuyahoga County Board of Health (www.ccbh.net) and Ohio Department of Health (www.odh.gov).

In the event that cases of emerging diseases, such as Rift Valley Fever, are identified in the Great Lakes region, one potential resource for collaboration is a group of partners that make up the Midwest Center of Excellence for Vector-Borne Disease (mcevbd.wisc.edu). This group is a combination of academic and public health researchers and experts from various locations in the Midwest who work together to better monitor, understand, control, and share information about mosquitoes, ticks, and the diseases they carry. Information obtained from this group could be utilized during a large public health event response, in addition to serving as a resource in establishing and advancing local vector control policies and programs.

Arthropod stings or bites from bees, wasps, etc. require availability and sufficient quantities of epinephrine for immediate injection and swift medical attention. Snakebite envenomation treatment is complex and requires close monitoring of symptoms and swift medical attention by qualified staff, as well as availability of sufficient antivenin. Adaption measures would include appropriate training for healthcare staff on how to respond to these types of events. Emergency protocols and procedures will need to be established to ensure prompt transportation of bite victims to local hospitals prepared for this type of emergency.
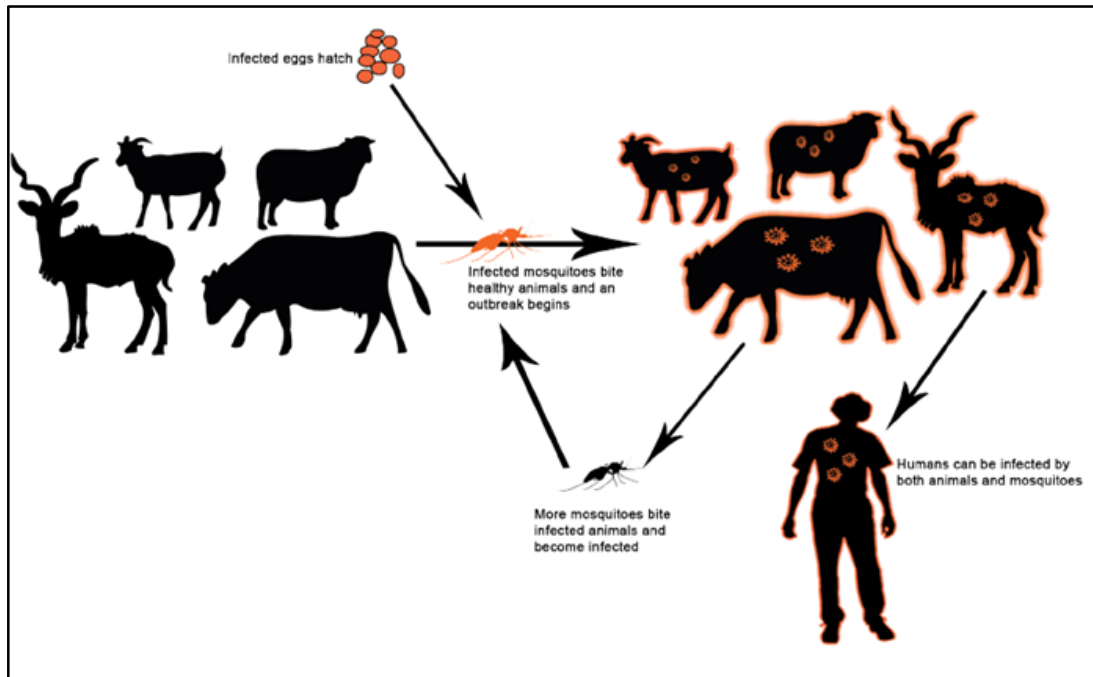
The spread of Rift Valley Fever, which illustrates the complex interrelation between mosquitoes, wild and domestic animals and humans. Copyright: EcoHealth Alliance and the National Institute for Communicable Diseases (NICD).

Impact of Climate Change and the spread of vector-borne disease in the USA:

Increase in Rift Valley Fever

The rapid spread of West Nile Virus (WNV) across the U.S. starting in 1999, shows the deficiencies and vulnerabilities of human and agricultural systems to deal with vector-borne viruses (Britch and Linthicum, 2007). It also highlights the need for the proactive implementation of multi-agency protocols to monitor and control disease-transmitting mosquito vectors.

U.S. scientists are concerned Rift Valley Fever (RVF) may potentially reach the United States (CIDRAP, 2004; Britch and Linthicum, 2007). It has not yet been determined if Rift Valley Fever would be well-suited for life in the colder northern states in the U.S. However, RVF has high potential for being introduced into the warmer, drier southern states, like Texas, New Mexico, Nevada and Arizona. These states have ecological conditions similar to eastern and southern Africa where RVF is endemic (Brand et al., 2018).

The introduction of RVF in the U.S. could potentially have more severe effects on human health than the West Nile Virus (CIDRAP overview RVF; Britch and Linthicum, 2007). It would also result in severe livestock mortality and considerable economic cost amounting to hundreds of millions of dollars (Britch and Linthicum, 2007). This was exemplified during a nation-wide 2010-2011 outbreak in South Africa. Along with 24 human deaths, a total of 14,342 livestock cases were reported on 489 farms, which conservatively had an agricultural impact of 295.3 million Rand. This equals approximately $40 million U.S. dollars at 2010 exchange rates (Brand et al., 2018; Msimang, et al., 2019).

References

- Brand R.F., Rostal, M.K., Kemp, A., Anyamba, A., Zweigers, H., Van Huyssteen, C.W., Karesh, W.B., Paweska, J.T., February 20, 2018, A phytosociological analysis and description of wetland vegetation and ecological factors associated with locations of high mortality for the 2010-11 Rift Valley fever outbreak in South Africa. PLOS ONE. https//doi.org/10.1371/journal.pone.0191585
- Britch S.C., and Linthicum K.J., 2007. Rift Valley Fever Working Group. Developing a research agenda and a comprehensive national prevention and response plan for Rift Valley fever in the United States. Emerg Infect Dis., Volume 13, Number 8. Available from http://www.cdc.gov/EID/content/13///e1.htm
- Kendrovski. V., and Gjorgjev, D., 2012. Climate Change: Implication for Food-Borne
- Linthicum K., Davies F., Bailey C., and Kairo A., 1984. Mosquito species encountered in a flooded grassland dambo in Kenya. Mosq News. http://cat.inist.fr/?aModele=affichN&cpsidt=8913484
- Msimang V., Thompson P.N., Jansen van Vuren P., Tempia S., Cordel C., Kgaladi J., Khosa J., Burt F.J., Liang J., Rostal M.K., Karesh W.B., and Paweska, J.T., 2019. Rift Valley Fever Virus Exposure amongst Farmers, Farm Workers, and Veterinary Professionals in Central South Africa. Viruses, 11, 140. doi:10.3390/v11020140 www.mdpi.com/journal/viruses

Water Supply and Waterborne Illnesses

Photo Credit: Bigstock

The Great Lakes cover an area of 95,160 square miles and contain 20% of the World's freshwater. This translates to approximately 6 quadrillion gallons.

INTRODUCTION

As drought potentially intensifies and freshwater resources are depleted in the U.S., the demand for water across the country will increase. Climate change will likewise influence freshwater quality and the likelihood of waterborne diseases. For the Great Lakes region, which holds one-fifth (20%) of the world's freshwater, the quantity of potable water will not be the main problem. Water quality will be the main concern. Water quality will decline because of an increase in the frequency of flooding, along with an increase in waterborne pathogens. Furthermore, water-related illnesses caused by toxins produced by harmful algae and cyanobacteria (blue-green algae) blooms, will increase. Water quality will also worsen due to the quantity of plastics and micro-plastics present, now an emerging major contaminant and

environmental health concern.

There is a complex relationship between climate change induced higher temperatures, higher rainfall, and increased runoff. In Cuyahoga County, runoff is largely derived from urban sources and spaces. Contaminants, including *E coli* from fecal matter, may also impair beach and stream recreation, and kill macro-invertebrates and fish. Additionally, water quality is reduced during heavy rain due to combined sewer overflows of storm water and raw sewage in antiquated combined sewers. This also affects the recharge of aquifers and contaminates groundwater and private wells. The outcome is a direct increase in potential waterborne illnesses caused by bacterial contamination.

Figure 6. The figure illustrates the complex ecosystem links between Climate Change, Water Quantity, Quality, and Human Exposure to Waterborne Illness.
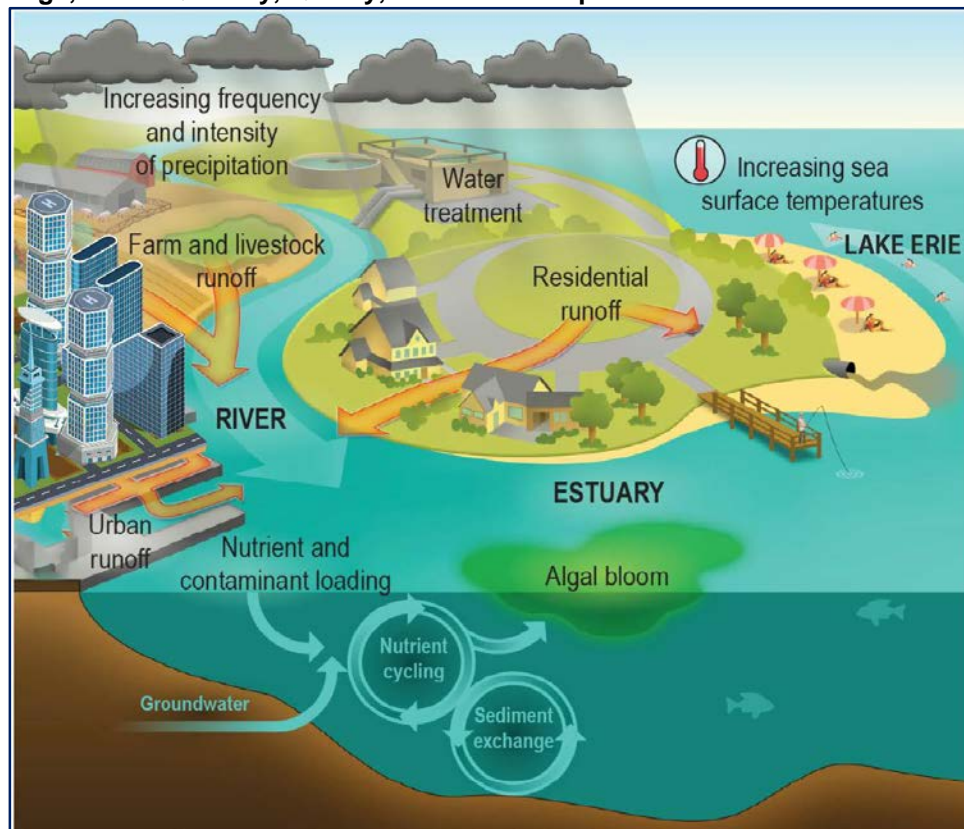
Figure 6 was modified from the U.S. Global Change Research Program; Chapter 6.

INCREASED STORMWATER AND FLOODING

More storms and intensity of rain will increase runoff and sewage contamination by *Escherichia coli* (*E. coli*) and other pathogenic bacteria, including Campylobacter species, Cryptosporidium and Giardia. CCBH works closely with the Northeast Ohio Regional Sewer District (NEORSD) to conduct storm water monitoring activities, which includes the sampling of storm water outfalls, streams and bathing beaches. In the event that *E. coli* levels rise above the EPA determined acceptable health standard, water quality advisories are issued at beaches until bacteria levels drop below prescribed thresholds.

ALGAL BLOOMS AND PH CHANGES

Algal blooms are a threat to fish, anglers, recreational users of Lake Erie beaches, and their companion animals. An increase in the average global temperature will also increase water temperatures, while prompting algal blooms and other toxic-microbial growth. For the shallow, western basin of Lake Erie, algae and bacteria growth is a major, ongoing problem. This issue is a result of land use and the agricultural practice of nitrogen and phosphorus-loading, coupled with meteorological conditions (Michalak et al., 2011).

Livestock waste and fertilizer runoff are a direct threat to human and ecosystem health. Ohioans currently farm approximately 14 million acres of land. Cuyahoga County dedicates only 1,984 acres to commercial farming, making livestock waste contamination less of a concern locally. However, it still poses a risk for Ohio and Lake Erie.

Algal blooms have been routinely monitored by the National Oceanic and Atmospheric Administration (NOAA). They have derived data predicting increased size and frequency of future algal blooms in all five Great Lakes, and in particular, Lake Erie.

In Lake Erie, *Microcystis* sp., and *Anabaena* sp., are the two most common genus of cyanobacteria that produce the toxin microcystin (Michalak et al., 2011). Several other toxins are also produced by cyanobacteria (Beversdorf et al., 2018), and typically function as either hepatic or neural toxins, which can cause death in extreme cases.

Toxic algal blooms have become an annual concern in Lake Erie, especially in the Western basin.

In the past decade, there has been extensive documentation of ocean acidification (pH change) caused by climbing CO_2 levels. Ocean Acidification causes coral bleaching and widespread die-off of reefs. This is devastating for marine ecosystem function. Little research has been done on potential acidification (pH change) in freshwater systems, particularly in the Great Lakes region. A study by Phillips et al., (2015), made projections of mean pH for the Great Lakes for the year 2100, showing an increase in pH, from 7.65 to 8.20. The effects of this projection will likely cause a decline in native muscle species and favor invasive mollusk species.

LEGIONNAIRES' DISEASE

Waterborne diseases, such as Legionnaires disease (legionellosis), occur as a result of exposure to pathogenic microorganisms, and chemically contaminated drinking water (Parr et al., 2015). Formally, Legionnaires disease is contracted from the Legionella bacterium– naturally found outdoors in soil and atomized water. However, the bacterium is known to contaminate indoor cooling systems, humidifiers, and cooling towers. It has also been responsible for deaths associated with exposure to contaminated water (Falkinham et al., 2015). Cases of legionellosis are increasing in the U.S., with an increase of 192% documented from 2000 to 2009 (Hicks et al., 2011). Legionellosis may become more prevalent in the midst of climate change, with higher temperatures and increased humidity, providing ideal indoor incubation conditions increasing transmission and deaths associated with Legionnaires disease (Cunha et al., 2015).

DROUGHT

Droughts may not post a significant threat to the Great Lakes region, however, drought and water shortage (caused by climate change and/or created by over exploitation of aquifers and rivers), will put additional stress on the Great Lakes to supply water to other regions for agriculture needs and human consumption. Potential international wars over water may displace vast amounts of people, increasing the number of refugees that immigrate to the U.S. and potentially relocate to the Great Lakes region.

Photo Credit: Janet Kay

An Extreme Weather Event: An approaching dust storm in a drought-stricken area driving red topsoil stripped from farm fields by extremely high winds.

WHAT IS THE LINK BETWEEN PLASTICS, CLIMATE CHANGE AND HUMAN HEALTH?

Plastics and Climate Change

The extraction of oil and the manufacturing of plastics produce emissions of Carbon Dioxide (CO_2), Methane, and other Greenhouse Gases. The production of just 1 kilogram (1 kg = 2.2 lbs.) of polyethylene (the most commonly used plastic for bags and bottles) releases approximately 6 kgs (13.2 lbs.) of CO_2. During incineration of plastics, as part of the recycling process, approximately 6 kgs (13.2 lbs.) of CO_2 is also created. The Plastic Pollution Coalition links extraction of oil, its refinement into petroleum products, and the manufacturing of plastics with climate change (Glazer, Plastics Coalition, 15th December, 2015). Details can be found at: http://www.plasticpollutioncoalition.org/.

Figure 7. A Venn diagram shows the simplistic relationship linking fossil fuel (oil) use, climate change and plastics.
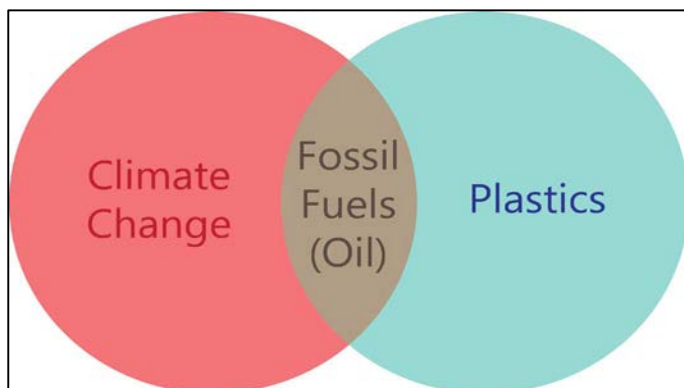

Figure 7. Created from an idea suggested by Elizabeth Glazner, Plastic Pollution Coalition.

Plastics are now ubiquitous in their use and occur throughout all aspects of society, including packaging, construction materials, piping, vehicle parts, toys, electronic devices, manufactured goods, etc. As a consequence, plastics are now found in all fresh and marine waters, including in the bottled water and beer we drink (Andrady, 2003, Wattigneya et al., 2018, Zbyszewski et al., 2014).

Solid plastics, particularly nano-plastics (one billionth of a meter; 10^{-9} of a meter in size) constitute an increasing hazard to ecosystems, freshwater and marine life and human health (Hidalgo-Ruz, et al., 2012).

Plastics and water pollution pose a significant concern for residents of Cuyahoga County and all of northern Ohio. Situated on the southern shore of Lake Erie, we will be impacted by the continued increase of plastics entering the five Great Lakes and causing environmental concerns for the world's largest body of freshwater (Baldwin et al., 2016; Wattigneya W.A., et al., 2018). As a result of current research on the water quality and plastic pollution in the Great Lakes, the World Health Organization declared plastics as a major hazard to human health (Hidalgo-Ruz, et al., 2012; Baldwin et al., 2016 Wattigneya et al., 2018).

Photo Credit: Bigstock

Plastic bottles and caps are the second most frequently found items in river clean-ups, as more than 22 billion plastic water bottles are thrown away annually. Each year in Cuyahoga County, over 319 million single-use plastic bags are discarded, adding 1 million tons of waste to landfills. The 'free' plastic bags provided at grocery stores are used for about 12 minutes but do not degrade for thousands of years. Plastic bags and plastic bottles are made from toxic chemicals and may even become breeding sites for disease-carrying arthropods and pathogenic micro-organisms. (https://www.theworldcounts.com/challenges/planet).

Phthalates (plasticizers): Toxic Effects on Human Health

Phthalates are commonly used chemicals in the production of plastics. They help soften plastics - the softer and more pliable the plastics, the more phthalates are used to obtain this effect. Phthalate-softened plastics are widely used to cover fresh and frozen meat, fish, cheese, baked goods and vegetables. Additionally, sandwiches and packed lunches are covered by plastic wrap. The health effects of this use have not been thoroughly documented.

As climate change continues to raise temperatures, these phthalates and other plastic chemicals will be released from discarded, single-use, plastic items. Single-use plastics, including plastic bags and water bottles, are now identified as one of the major items littering our waterways, including Lake Erie and the Great Lakes (Baldwin et al., 2016).

Single use cups and containers also present concerns for a different reason, particularly those in which fluids are heated in microwave ovens or boiled in kettles. These items are problematic as the toxic plasticizing chemicals (phthalates) are released into the liquid when the substance is cooked or heated. Consequently, most people in the U.S. have been exposed to phthalates. The results from studies conducted by the Centers for Disease Control and Prevention (CDC) show that the majority of people in the U.S. have measurable levels of phthalates in their urine (Kohn et al., 2000). Phthalates include compounds that are carcinogenic, mutagenic, and act as endocrine-disruptors, which are known to cause severe hormone disorder in the reproductive systems of both males and females (Kohn 2000, Tickner 2001, Mendes 2002, Lovekamp-Swan 2003, Latini et al., 2006, CDC Phthalate Fact Sheet, Human Health Statement for Phthalate 2010).

MITIGATION AND ADAPTION

The Northeast Ohio Regional Sewer District's (NEORSD) combined sewer overflow Project, Project Clean Lake, and their Green Infrastructure Grants Program are examples of how municipalities, businesses and organizations in a region can work together to help manage storm water and address water quality concerns. To find out more about the Clean Lake Project, please visit: About Project Clean

Lake – Northeast Ohio Regional Sewer District (neorsd.org). More information about the NEORSD's Green Infrastructure Grant Program is available at: Green Infrastructure Grant Program – Northeast Ohio Regional Sewer District (neorsd.org)

The reduction of toxic algal blooms in Lake Erie will require a change in land use and nutrient intensive agricultural practices. This would necessitate minimizing the use of phosphates and nitrates on land, thus reducing them in runoff, which in turn, would provide less nutrient-rich waters for algae to reproduce.

Since no vaccines exist to prevent Legionnaires disease, the key to reducing the risk of Legionella growth in the water systems and devices in health care facilities, long-term care facilities, businesses, residential buildings and any other structures with building water systems is to implement appropriate maintenance and control measures, including developing and following a water management program. Details can be found at: Legionnaires' Disease | The Joint Commission and Prevention of Legionnaires Disease | CDC .

Mitigation and adaptation strategies may not be directly applicable for plastics use, however, a combination of education and policy adoption are essential to change current attitudes towards the use of plastic bags and single-use items, such as straws, drink stirrers, chopsticks, and plastic cups. The use of plastic packaging must be reduced, particularly clear, plastic wrapping, which uses phthalates. Plastic cigar holders and cigarette filters are additional items that need to be addressed, as both serve as one of the prominent sources of debris found on beaches and in wastewater treatment plants.

REFERENCES

- Anderson, E.J., Schwab, D.J., Lang, G.A., 2010. Real-time hydraulic and hydrodynamic model of the St. Clair River, Lake St. Clair, Detroit River system. J. Hydraul. Eng. 136, pp 507-518.
- Andrady, A.L., 2003. Plastics in the environment. In: Andrady, A.L.(Ed.) Plastics and the Environment. John Wiley & Sons, Inc., New Jersey.
- Baldwin, A.K., Corsi, S.R., and S.A., Mason, 2016. Plastic Debris in 29 Great Lakes Tributaries: Relations to Watershed Attributes and Hydrology. Environ. Sci. Technol. 50, 10377-10385
- County of Cuyahoga, 2018. Cuyahoga County Proposed Carryout Bag Fee-FAQs,
- Hidalgo-Ruz, V., Gutow, L., Thompson, R.C., and Theil M., 2012. Microplastics in the Marine Environment: A Review of the Methods Used for Identification and Quantification. Environ. Sci. Technol. Dx.doi.org/10.1021/es2031505
- Journal of Great Lakes Research, Vol 40, pp. 288-299. http://dx.doi.org/10.1016/j.jglr.2014.02.012
- Kabir, M.M., Hossain, C.R., Shimizu, K., 2017. Can Bio-plastics Replace Non-Biodegradable Plastics? J Appl Biotechnol Bioeng 3(4): 00074. DOI: 10.15406/jabb.2017.03.00074
- Proceedings of the international research workshop on the occurrence, effects, and fate of microplastic marine debris. In: Arthur, C., Baker, J., Bamford, H. (Eds.), NOAA Technical Memorandum NOS-OR&R-30.
- Shah, A.A., Hasan, F., Hameed, A., and Ahmed, S., 2008. Biological degradation of plastics: a comprehensive review. Biotechnol. Adv. 26, pp. 246-265.
- UNEP and GRID-Arendal, 2016. Marine Litter Vital Graphics. United Nations Environment Programme and GRID-Arendal. Nairobi and Arendal www.unep.org, www.grida.no
- Wattigneya, W.A., Irwin-Barnwella, E., Lia, Z., Davisb, S.I., Manentec, S., Maqsoodc, J., Scherd, D., Messing, R., Schuldt, N., Hwangg, S-A., Aldoush, K.M., Lewis-Michl, E.L., and Ragin-Wilsona A., 2018. Biomonitoring programs in Michigan, Minnesota and New York to assess human exposure to Great Lakes contaminants, International Journal of Hygiene and Environmental Health, in press.
- Zbyszewski, M., Corcoran, P.L., Hockin, A., 2014. Comparison of the distribution and degradation of plastic debris along shorelines of the Great Lakes, North America.

Air Quality

Photo credit to Roger Dallas

INTRODUCTION

Air Quality is reduced by emissions from vehicles and industry. Vehicle emissions include soot (solid particulate matter), Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O) and Hydrofluorocarbons (HFCs). These harmful emissions combined with ground-level Ozone, pollen and fungal spores are increasing exacerbated by climate change. Air pollutants and emissions pose a threat to human health, particularly infants, children, elderly, asthmatics, and chronic lung disease sufferers.

If a 26.5 foot cube, the size of a small house, represents one ton of CO_2, how would it look if 25 million tons are added annually to the atmosphere?
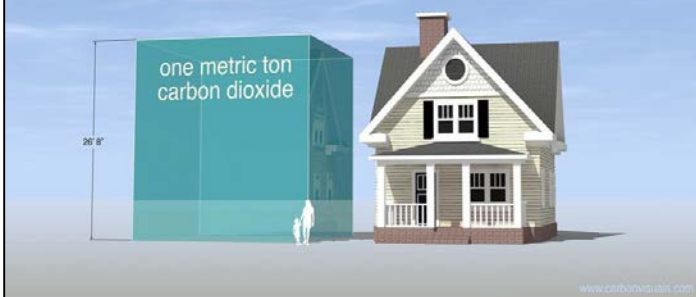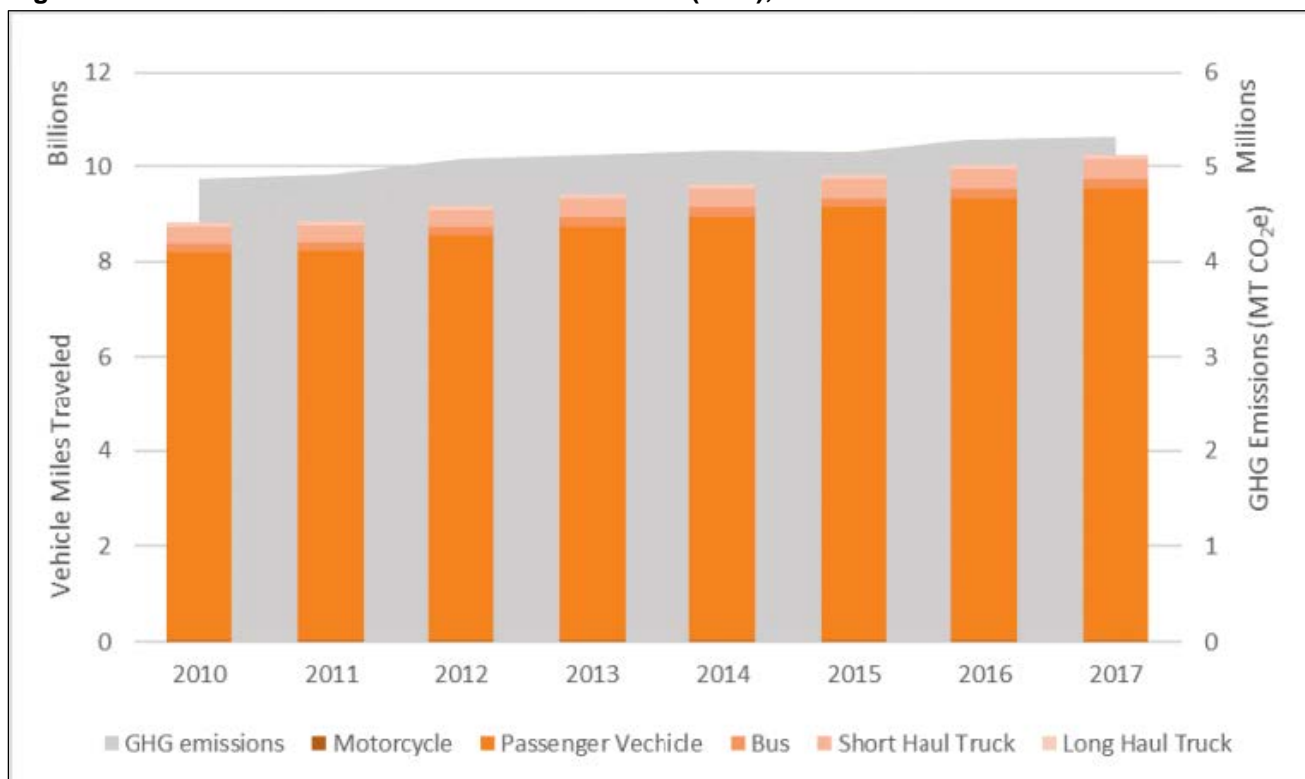

AIR POLLUTANTS AND EMISSIONS

Total Greenhouse Gas emissions for Cuyahoga County are derived from four sources; stationary energy (natural gas, electricity), transportation, waste and industrial processes (Cuyahoga County Greenhouse Gas Emissions Inventory). In 2010, nearly 25 million MT CO_2e (Metric Tons of Carbon Dioxide equivalent) were emitted in Cuyahoga County. In 2019, emissions dropped to approximately 22.2 MT CO_2e. This represents a decrease of just over 11% of total emissions. Details on the Greenhouse Gas Inventory can be found at: https://www.countyplanning.us/projects/climate-action-plan/greenhouse-gas-emissions-inventory-dashboard.

Figure 8. Total emissions and Vehicle Miles Travelled (VMT), between 2010 and 2017.


The figure illustrates a steady increase in vehicle emissions and miles traveled. Figure 8 from NOACA (2017 data), Brendle Group (2018 study), details in Cuyahoga County Climate Action Plan (CCCCAP, 2018).

While overall emissions may have decreased between 2010 and 2019, emissions from transportation in Cuyahoga County actually increased during this period. Passenger vehicles comprise 78% of emissions and make up 93% of all Vehicle Miles Traveled (VMT). The data presented in Figure 8 depicts a steady increase in VMT over recent years, and consequently, rising transportation emissions as well. For a single year (2017), in Cuyahoga County, the length traveled amounted to just over 10 billion miles. This distance equals a thousand round trips to the moon, or 501,800 trips to circumnavigate the earth. Additional details on all sources of Cuyahoga County emissions can be found in the Cuyahoga County Climate Action Plan. (CCCCAP, 2018)

Along with CO_2, other harmful pollutants from vehicle emissions include: Methane (CH_4), Nitrous Oxide (N_2O, and Hydrofluorocarbons (HFCs). Figure 9 identifies that the per-capita emissions in Cuyahoga County totaled 18.82 $MTCO_2e$ in the year of 2017. While this number falls slightly below the state and national average of per-capita emissions, Cuyahoga County still emits more GHGs than many other, highly

urbanized cities and counties.

Figure 9. Per-Capita emissions in Cuyahoga County compared with other locations
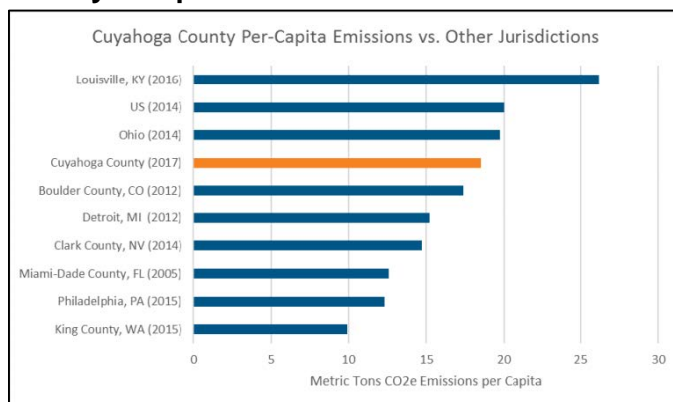
Model-based Greenhouse Gas (GHG) emissions for the U.S., show CO_2 accounts for 99.3% of emissions from the transportation sector, while Methane (CH_4) makes up 0.61%, and Nitrous Oxide (N_2O) 0.09%. The hydrofluorocarbon (HFC) emissions from air conditioners are too small to measure and model (Brendle Group study, 2018).

"A typical passenger vehicle emits about 4.6 metric tons of carbon dioxide per year."
(https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle).

Take Action Against Climate Change: Synchronize Traffic Lights

We have all experienced the frustration of sitting at traffic lights, accelerating to the next one, only to be stopped again and again! In the U.S., very few states and cities have synchronized their traffic lights to facilitate smooth traffic flow, which would reduce CO_2, CO, and NOx emissions, along with other harmful pollutants. Synchronized traffic lights would also save fuel costs and help minimize consumption. Parts of California, Florida, Washington, Minnesota, Maryland, Georgia, and Texas are attempting to synchronize traffic lights. This action would allow a smoother flow of traffic, which in turn reduces road congestion and air pollution by 10% - 20% (Jacquot, 2008). Additionally, the National Transportation Operations Coalition estimated that roughly 75% of the country's 300,000 traffic signals need to have their timing adjusted or lights replaced (Jacquot, 2008). Research completed in the city of Celaya, Guanajuato, Mexico (Mondragón,et al., 2016), and by Li and Shimamoto (2011) showed the synchronization of traffic lights dramatically reduced harmful pollutants, CO_2 emissions and saved on fuel and fuel costs. The use of Intelligent Transportation Systems (ITS) has also been shown to reduce Carbon Monoxide (CO), Hydrocarbons (HC), Carbon Dioxide (CO_2), Particulate Matter (PM), Oxides of Nitrogen (NO_2), and other harmful pollutants (Nasir et al., 2014). Replacing traffic lights with roundabouts showed similar reductions in GHG emissions as well as in reducing traffic accidents (Meneguzzer, et al., 2016).

Airborne Particulate Matter

Airborne Particulate Matter (PM) is derived from a mix of natural and human sources, composed of liquid and solid materials suspended in the atmosphere as aerosols. These include sulfate, nitrate, ammonium, organic and elemental carbon, inorganic mineral dust, and in coastal areas, sea salt. The main components of particulate matter come from vehicle emissions, with diesel engines producing the worst amount of PM. Other PM emitters include coal-burning power plants, factories, and other manufacturers that utilize processes that produce carbon and other solid particle emissions.

Black carbon (soot) or elemental carbon is created when insufficient oxygen is available for complete combustion, which can cause both health issues and environmental concerns. When particulate matter is smaller than 10 micrometers in size, such as black carbon, which is actually less than 2.5 micrometers, the particles in the air are capable of penetrating into the alveoli in the lungs, and even entering the blood stream. Particulate matter poses a serious health problem for asthmatics and people with lung-related diseases (EPA, 2009, 2018). Climate change will increase precipitation, temperature and humidity, which in turn affects the atmospheric level of PM (Dawson et al., 2009). There will be an increase in fine particulate matter, and this increase in PM will in turn be responsible for increasing respiratory-related health problems and allergenic disease associated with poor air quality (Tagaris et al., 2009).

Ground-level Ozone (O$_3$)

Ground level ozone is created when fossil fuel and vehicle exhaust pollutants combine with nitrogen and other chemicals in the atmosphere and then react with sunlight (Cromer et al., 2016). High concentrations of ground-level ozone, coupled with the heat island effect (refer to section 1.2), poses considerable human health risk (Filleul, et al., 2006).

In 2016, the American Lung Association released a report that ranked cities and assigned a grade rating (A through F) related to ozone pollution. In this report, Cleveland ranked 27th in the U.S. for ozone pollution and earned an F grade. Additionally, in 2016, Greater Cleveland had sixteen "Ozone Action" days. An "Ozone Action" day can be declared by a local municipality, county or state, and typically occurs at certain times during the summer months, when weather conditions (such as heat, humidity, and air stagnation) run the risk of causing health concerns.

A study conducted by the Northeast Ohio Areawide Coordinating Agency (NOACA) found that ozone pollution may have been responsible for up to 384 deaths in 2013.

ALLERGENS

The origin of climate-related allergenic responses can be divided into two categories:

- Organic influences:
  - e.g., pollen and fungal spores, which cause a protein response in the human body to produce antihistamines.
- Environmental influences:
  - e.g., rising levels of GHG's, ground-level ozone, carbon and soot, and other particulate matter.

These allergens are influenced by wind, rain, and related meteorological dispersal factors.

Asthma and Pollen

Climate change plays a role in the prevalence and severity of asthma, which is also exacerbated by ethnicity, poverty, city living, and pollution. Asthma is a chronic lung disease which affects 34 million people in the U.S. (Reid and Gamble, 2009), including 7 million children (EPA, CDC). A 2009 study completed by Case Western Reserve University's Prevention Research Center for Healthy Neighborhoods found that 12% of Cleveland's population has suffered from asthma.

Rising temperatures and CO$_2$ levels will increase the length of the growing season (George et al., 2007). Consequently, this will allow a population boom in the plant species which produce allergenic pollen (Rasmussen et al., 2017). The most significant of these allergenic pollen producing plants are the Common Ragweed (*Ambrosia artemisiifolia L.)* and the Greater Ragweed (*Ambrosia trifida L.).* Both contribute to human allergic reaction to pollen (Rasmussen et al., 2017).

Dense stands of Ragweed (Ambrosia spp.) produce massive quantities of pollen responsible for asthma and allergies.

Mold and Fungal Spores

Increased precipitation and resulting damp conditions will provide ideal conditions for mushroom and other fungal growth. All fungi produce spores, some of which have a more negatively pronounced effect on human health. The black mold (*Stachybotrys ssp.)* commonly found in basements can cause major anaphylactic reactions in susceptible humans, especially in infants and immunocompromised populations (CDC, 2017).
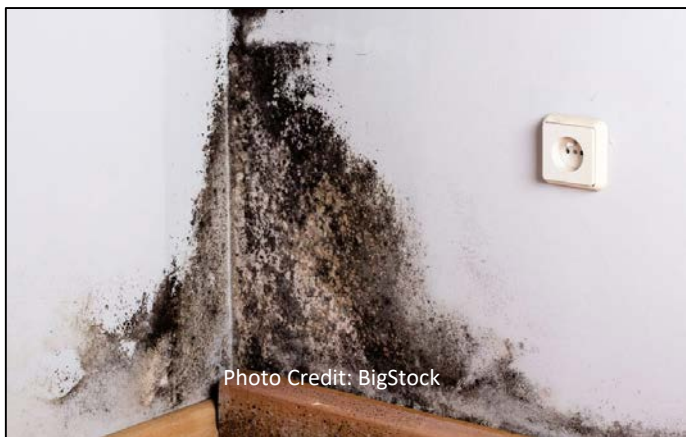

Damp conditions in basements and unventilated spaces provide ideal sites for increased growth of black mold, a serious cause of lung infection.

Mushrooms and Climate Change

Increased rain induced by climate change will result in longer, damp conditions and the potential for increased flooding of low-lying areas and basements. The dampness will provide ideal conditions for mushroom and fungal growth, exacerbating respiratory diseases like asthma. As a result, an increase in the foraging and eating of wild

Increased humidity provides ideal conditions for increased growth of mushrooms, including toxic species.

mushrooms collected in forests may occur. The consumption of wild-foraged mushrooms has periodically resulted in the poisoning of those collecting and ingesting certain species of mushrooms.

Numerous reports over the years have indicated that poisonous mushrooms were gathered in the wild by refugees. This activity puts new immigrant populations at increased risk of mushroom poisoning, since their cultural practices include collecting and eating foods from the wild. Toxic mushroom species look similar to edible mushrooms they may have collected in the past in other regions of the world.

The Death Cap mushroom (*Amanita phalloides*) (Vaill. ex Fr.) Link (1833), if eaten, may cause irreparable liver damage and death unless the patient receives immediate medical care, often requiring a liver transplant. In December 2016, 14 patients residing in Northern California were admitted to the hospital after ingesting *Amanita phalloides.* Ultimately, three required liver transplants (Vo et al., 2016). Refugees and new immigrants often have a different perspective – one that relies on woods, forests, rivers, and streams as natural resources, which are there to provide food to be gathered or fish to be caught and eaten (Taylor et al., 2005, Poe et al., 2014). Find out more at: https://www.ideastream.org/news/catching-and-eating-fish-from-cuyahoga-river-impacts-health-of-refugee-populations.

MITIGATION AND ADAPTATION

There are many strategies that could potentially improve overall air quality. Updated environmental policies and some variation of the carbon tax are requisites to improving poor air quality. This includes reducing CO_2 emissions and alleviating allergens and respiratory conditions related to airborne particulate matter and ground-level ozone. In addition, creating and enacting policies that encourage the use of hybrid and electric vehicles would also reduce emissions. Adjusting or removing selected traffic lights to allow a smoother traffic flow would reduce CO_2, CO, and NOX emissions, solid particulate matter (soot) and save fuel and transportation costs.

To minimize allergens, the management of both species of Ragweed (*Ambrosia trifida L. and A. artemisifolia L.*) may also alleviate seasonal allergic asthma attacks. Ohio State University's website provides material on the biology and management of Giant Ragweed (*Ambrosia trifida L.*).

Educational outreach, workshops, and the distribution of informational materials in numerous languages can be conducted to help educate people on the dangers of eating foraged mushrooms. In 2018, several workshops and training sessions were provided to the members of the Bhutanese/Nepali refugee community on this topic.

Establishing policies that focus on decreasing ground-level ozone are essential. Adaptation for ground-level ozone was described in a collaborative study between the American Thoracic Institute and the Marron Institute of Urban Management at New York University (NYU). The study ultimately determined that lowering the current EPA standard for ground-level ozone from 7ppb to 6ppb and the fine particulate standard of 35mg/m3 to 11mg/m3 was necessary. This study also indicated that lowering these levels would save 578 lives throughout Ohio (Cromar et al., 2016). It also projected that approximately 1,269 Ohioans and 487 Greater Clevelanders could avoid lung diseases as a result.

REFERENCES:

- Dawson, J.P., Bloomer, B.J., Winner, D.A., and Weaver, C.P., 2014. Understanding the meteorological drivers of U.S. particulate matter and concentrations in a changing climate. Bulletin of the American Meteorological Society, 95, pp. 521-532. doi:10.1175/BAMS-D-12-00181.1
- EPA, 2009. Integrated Science Assessment for Particulate Matter. National Center for Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Parks, NC.
- George, K., Ziska, L.H., Bunce, J.A., and Quebedeaux, B., 2007. Elevated atmospheric CO_2 concentration and temperature across an urban-rural transect. Atmospheric Environment, 41, pp. 7654-7665. doi:10.1016/j.atmosenv.2007.08.018
- Jacquot, J.E., May 16th 2008. Fix those Traffic Lights to Reduce Congestion (And Emissions). https://www.treehugger.com>Transportation>Cars
- Jurado E., Dachs J., Duarte C.M., Simo, R., 2008. Atmospheric deposition of organic and black carbon to the global oceans, Atmospheric Environment, Vol 42, 34, pp. 7931-7939. https://doi.org/10.1016/j.atmosenv.2008.07.029
- Li, C., and Shimamoto, S. September 2011. Dynamic Traffic Light Control Scheme for Reducing CO_2 Emissions Employing ETC Technology. International Journal of Managing Public Sector Information and Communication Technologies (IJMPICT), Vol. 2, No. 1, DOI: 10.5121/ijmpict.2011.2101
- Meneguzzer, C., Gastaldi, M., Rossi, R., Gecchele, G., Prati, M.V., 2017. Comparison of exhaust emissions at intersections under traffic signal versus roundabout control using an instrumented vehicle. 10-15 July 2016 World Conference on Transport Research-WCTR 2016 Shanghai. Transportation Research Procedia 25 (2017) 1597-1609. ScienceDirect. Available online at www.sciencedirect.com
- Mondragon, J.E., Garcia, J.A.J., Flores, J.M.M., Vasquez, S.T., and Lopez, J.A.V., 2016. Experiments Simulation and Design to Set Traffic Lights' Operation Rules. CIT2016-XII Congreso de Ingenieroa del Transporte

Valencia, Universitat Politecnica de Valencia, 2016. DOI: http://dx/doi.org/10.4995/CIT2016.2016.4093

- Nasir, M.K., Noor, R.M., Kalam, M.A., and Masum, B.M. 2014. Reduction of Fuel Consumption and Exhaust Pollutant Using Intelligent Transport Systems. Vol. 2014, Hindawi Publishing Corporation, Scientific World Journal, Article ID 836375, 13 pages. http://dx.doi.org/10.1155/2014/836375
- Rasummen, K., Thyrring, J., Muscarella, R., and Borchsenius, F., 2017. Climate-change-induced range shifts of three allergenic ragweeds (Ambrosia L.) in Europe and their potential impact on human health. PeerJ. 5: e3104.PMC 5357339 PMID 28321366
- Reid, C.E., and Gamble, J.L., 2009. Aeroallergens, allergic disease, and climate change: Impacts and adaption. EcoHealth, 6, pp. 458-470. doi:10.1007/s10393-009-0261-x
- Tagaris, E., Liao, K.J., DeLucia, A.J., Deck, Amar, P., and Russell, A.G., 2009. Potential Impact of climate change on air pollution-related human health effects. Environmental Science & Technology, 43, pp. 4979-4988. doi:10.1021/es803650w

Allergens, Asthma, Fungal Spores and Mushroom Poisoning:

- Asthma and Allergy Foundation of America 2018 Report. https://www.aafa.org/media
- Asthma in the U.S. 2011. Growing Every Year, Centers for Disease Control Vital Signs. https://www.cdc.gov/ashthma/most_recent_data.htm
- Center for Disease Control Most Recent, Asthma Data updated May 2018 https://cdcgov/vitalsigns/asthma/
- Centers for Disease Control Viral Signs Morbidity and Mortality Report May 6th 2011. https://www.cdc.gov/vitalsigns/asthma/

- Cromar, K.R., Gladson, L.A., Perlmutt, L.D., Ghazipura, M., and Ewart G.W., 2016. American Thoracic Society and Marron Institute Report Estimated Excess Morbidity and Martality Caused by Air Pollution above American Thoracic Society-Recommended Standards, 2011-2013. Ann Am Thorac Soc Vol 13, No 8, pp 1195-1201, DOI 10.1513/AnnalsATS.201602-103AR. Internet address: www.atsjournals.org
- Declet-Barreto, J., Knowlton, K., Jenerette, G.D., & Buyantuev, A. (2016). Effects of urban vegetation on mitigating exposure of vulnerable populations to excessive heat in Cleveland, Ohio. Weather, Climate, and Society, 8(4), 507-524. https://doi.org/10.1175/WCAS-D-15-0026.1
- Filleul, L., and Coauthors, 2006. The relation between temperature, ozone, and mortality in nine French cities during the heatwave of 2003. Environ. Health Perspect., 114, 1344-1347, doi:10.1289/ehp.8328.e32
- Poe M.R., LeCompte J., McLain R. and Hurley P., 2014. Urban foraging and the relational ecologies of belonging Social & Cultural Geography, Vol. 15, No. 8, pp. 901-919. http://dx.doi.org/10.1080/1469365.201.4.908232
- Scheil, W., 2011. Medicinet.com Asthma Cases Are Increasing: Are Environmental Exposures to Balme. https://medicinet.com/asthma_rates_increasing/views.htm
- Taylor, B.R., Kaplan J., Hobgood-Oster, L., Ivakhiv, A.J., and York, M, 2005. The encyclopedia of religion and nature. London; New York: Thoemmes Continuum, 2005
- Vo KT, Montgomery ME, Mitchell ST, et al., 2017. Amanita phalloides Mushroom Poisonings-Norhern California. MMWR Morb Mortal Wkly Rep., 2017;66 pp. 548-553. DOI: http://dx.doi.org/10.15585/mmwr.mm6621a1

Photo Credit: https://www.clevelandmetroparks.com/parks/visit/parks/lakefront-reservation

Mental Health and Well-being

INTRODUCTION

Rising temperatures and extreme weather events, like drought, wildfires, flooding, and snowstorms, cause an increase in peoples' anxiety and stress levels and lead to a sense of helplessness (Clayton et al., 2014). Figure 10 illustrates the cyclical nature of climate change impacts on human mental health and well-being. They are detailed in Chapter 8 of the United States Global Change Research Program's (USGCRP) *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment* (2016). At the center of the diagram are human figures representing adults, children, the elderly, and people with disabilities. The outer circle depicts climate impacts, such as heat, wildfires, storms, drought, etc. The listed climate impacts are interconnected with and affect three health domains; Medical and Physical Health, Mental Health and Community Health.

Health care providers share concerns regarding the public's awareness of the global public health crisis resulting from climate change. So much so, that an article in the Frontiers in Ecology and the Environment has a headline stating: *"Worried about climate change? Ask a Doctor"* (Front Ecol Environ, June, 2019. Vol. 17(5). Doi:10.1002/fee.2051). It describes how the Planetary Health Alliance (PHA) launched Clinicians for Planetary Health, a new community for medical practitioners who are concerned about the negative health impacts of human caused (anthropogenic) climate change (lancet, May 2019. Volume 393, Issue 10185).

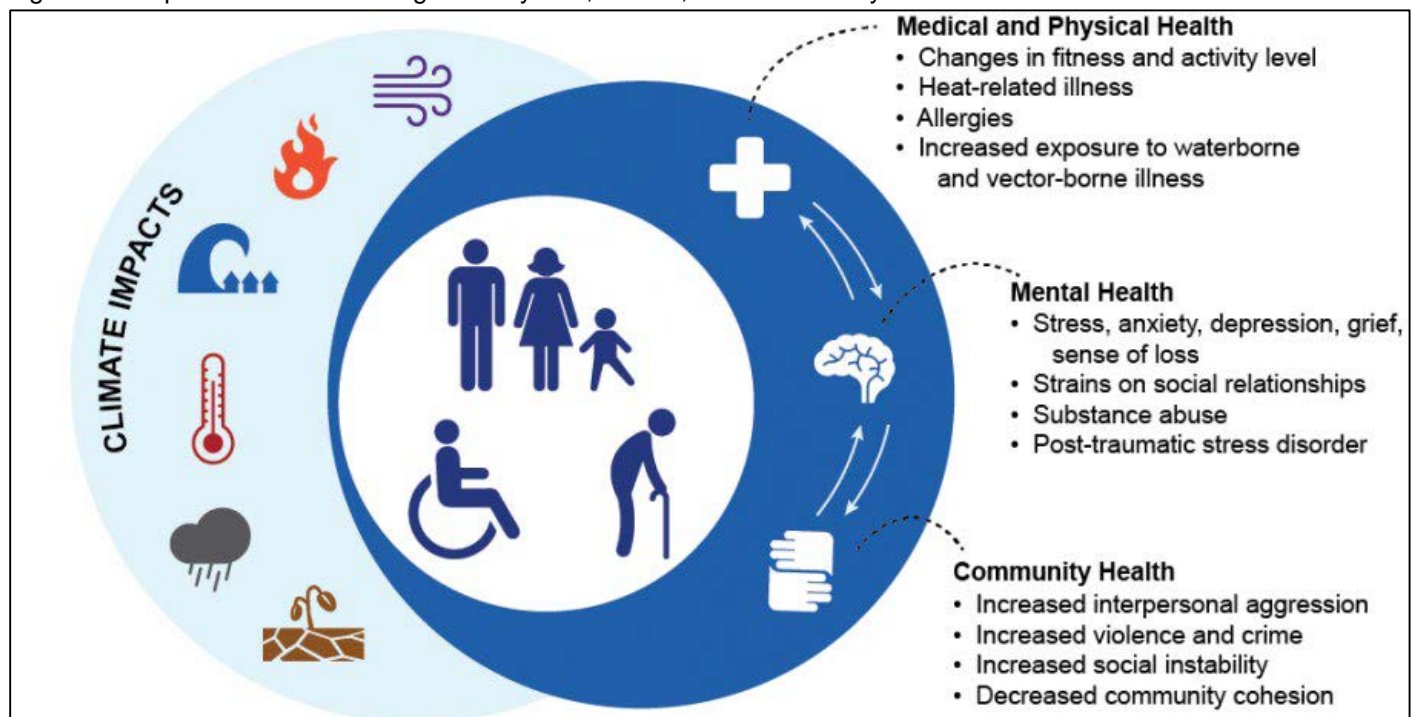Figure 10. Impact of Climate Change on Physical, Mental, and Community Health

Figure 10. Adapted from Chapter 8, USGCRP. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment* (2016).

VULNERABLE POPULATIONS

The populations most vulnerable to the health impacts of climate change include:

- Children under 5 years of age
- Elderly
- Pregnant women
- Postpartum mothers
- Veterans
- Hospitalized
- People suffering from pre-existing mental health issues
- Substance abuse sufferers
- Economically disadvantaged
- Emergency workers
- First responders (EMS, law enforcement and firefighters)

The locations of these vulnerable groups (e.g., kindergartens, hospitals, elder-care facilities, etc.) need to be identified and accounted for in emergency response plans. These plans would be implemented when weather forecasts predict extreme weather events. Proactive management practices should be developed and implemented ahead of emergency responses.

EXTREME WEATHER EVENTS

Extreme Weather events include days when the temperature rises above 95°F (30°C) and humidity is over 60%. Crime has been shown to increase as temperature and humidity rises above these levels. Additional discussion on the relationship between extreme heat-days and potential increases in crime is provided in Section 1– Extreme Weather.

THE THREAT OF CLIMATE CHANGE AS A STRESSOR

People routinely hear about climate change and its impacts on the environment on social media, while listening to the radio, reading newspapers, and watching television. Images of events like forest fires show the devastation and loss of life that can occur after severe weather events. People may feel strong emotional responses to these events, which act as stressors causing worry and anxiety. Other wide-ranging, negative psychological influences include distress, grief, sadness, sense of loss, and PTSD-like symptoms.

These feelings are often accompanied by guilt and an inability to help or change the situation. This engenders a pessimistic outlook, which erodes the sense-of-self, and adds to the collective loss of control over the environment and one's home (USGCRP 2016, Chapter 8).

FEELINGS OF HELPLESSNESS

Individuals can develop feelings of helplessness as they feel they can do nothing to prevent or lessen natural disasters caused by climate change. These feelings can become debilitating, and may include concerns related to extreme weather and flooding, diseases transmitted by arthropod vectors, allergies from pollen, fungal spores, exhaust emissions, and exposure to chemicals (i.e. lead, mercury or asbestos). A new and rapidly increasing source of anxiety now includes plastics and the global effects on all water and life.

Exercise reduces depression and anxiety (Carek, et al., 2011). As little as one hour, twice a week of a vigorous workout or energetic walking significantly improves physical and mental health and the sense of well-being (Dunn et al., 2005).

The sound of running water, such as a gurgling brook, flowing stream or the braking waves on Lake Erie shores, is well known to calm the mind. Jogging, walking or fishing may also have the same calming effect and act to alleviate depression (O'Neal et al., 2000).

SUICIDE

Growing anxiety over climate change adds to the concerns those already experiencing mental health issues are dealing with. Currently, suicide is the second leading cause of death in ages 10-34, with over 44,965 suicides a year ("Suicide Facts"). There is a strong positive linear relationship between unusually hot days and suicide rates, and climate change could potentially cause an additional 26,000 suicides in the U.S. by 2050, or just under 1,000 people per year (Meyer [Page 1]).

For more information on this topic, visit Climate_changes_mental_health.ashx (apha.org)

Photo Credit: BigStock

Planting trees can be good for your well-being along with being an immediate mitigation process absorbing atmospheric carbon as the tree grows.

MITIGATION AND ADAPTATION: Health Benefits from Trees and Forests

Looking at trees and greenery improves the sense of well-being, mental and physical health (Akers et al., 2012; Li and Kawada, 2010). Numerous studies have shown at least eight important physical and mental health benefits from looking at trees and walking in forests (Kaplan and Kaplan, 1989; Donovan et al., 2013; Hanson et al., 2016). Large portions of Cuyahoga County and the City of Cleveland are highly urbanized. Improving and enlarging existing urban green spaces will help provide urban populations with access to trees and open spaces, and will potentially improve the public's health and well-being (Lee et al., 2009; Li, 2010; Maas et al., 2006).

Walking in the Woods (Forest Bathing)

As the impacts of climate change on mental health already pose serious concerns, it is imperative that people learn different ways to cope with added levels of anxiety, stress, and depression. One coping mechanism which originates from the early 1980's in Japan is known as Shinrin-yoku. The concept of

Shinrin-yoku, literally translates to "forest bathing", and is the act of taking in the atmosphere of a forest while walking, sitting or standing under its' trees. Forest bathing is a deliberate, mindful, meditative act of exploring and expanding one's senses and focusing attention to the surrounding forest. Forest bathing is recognized as a legitimate form of nature therapy, with documented health benefits (Lee et al., 2009; Li 2010; Li, Q., and Kawada, T., 2010).

Educational Outreach

Educational events and open discussion should be utilized to allow people to better understand climate change, its causes, and the strategies that can be undertaken to help cope with it. Group discussions and outreach opportunities provide people with the ability to express their particular fears and anxieties. This can help individuals feel that their input can make a difference and instill a general feeling of cooperation. It also helps develop resilience in an individual, household, and community when people work together to identify how best to prepare for and adapt to climate change.

Things you can do to reduce the impact climate change, and which may help improve your sense of well-being:
- Conduct an energy audit and insulate your home
- Plant trees instead of only lawns
- Install rainwater gardens
- Reduce impermeable paved surfaces
- Reduce the use of solid waste, including plastics
- Recycle paper, glass, plastic, etc.
- Compost
- Reduce water use
- Install solar panels
- Walk instead of drive
- Buy a hybrid or electric vehicle
- Start a home garden
- Become involved in community gardens

References:

- Akers, A., Barton, J., Cossey, R., Gainsford, P., Griffin, M., Mikleright D. (2012). Visual Color Perception in Green Exercise: Positive Effects on Mood and Perceived Exertion. Environmental Science and Technology. 46(16):8661-8666. http://www.ncbi.nlm.nih.gov/pubmed/22857379. Clayton, S., Manning, C.M., and Hodge C., 2014. Beyond Storms & Droughts: The Psychological Impacts of Climate Change. 51 pp., American Psychological Association and ecoAmerica, Washington, D.C. URL | Detail

- Curtin, S.C., Warner, M., Geedegaard, H., 2016. Increase in suicide in the United States, 1999-2014. NCHS data brief, no, Details on priority group enrollment criteria can be found at: http://www.va.gov/HEALTHBENEFITS/resources/priority_groups.asp (pg 6)

- Harris, E.C. and Barraclough, B., 1997. Suicide as an outcome for mental health disorders. A meta-analysis. Br J Psychiatry, 170, pp. 205-228 (pg 8)

- Pon, B., 1999. Pavement Albedo. Heat Island Group. Archived from the original on 29 August 2007. Retrieved 27 August 2007.

- Public Health. https://toolkit.climate.gov/topics/human-health/building-climate-resilience-health-sector

- US Department of Veterans Affairs reference: http://www.va.gov/vetdata/docs/pocketcards/fy2016q3.pdf

- See Mary Christina Wood, Professor of Law, Oregon School of Law

- Akers, A., Barton, J., Cossey, R., Gainsford, P., Griffin, M., Mikeleright, D. (2012). Visual Color Perception in Green Exercise: Positive Effects on Mood and Perceived Exertion. Environmental Science and Technology. 46(16):8661-8666. http://www.ncbi.nlm.nih.gov/pubmed/22857379

- Blumm M.C., 2013. The Public Trust Doctrine in Natural Resources Law, Carolina Academic Press.

- Coghill, K., Sampford, C., and Smith, T., (eds), January 2012. Atmospheric Trust Litigation Around the World, chapter in: Fiduciary Duty and the Atmospheric Trust Ashgate Publishing (Australia)

- Donovan, G. Butry, D. Michael, Y., Prestemon, J., Liebhold, A., Gatziolis, D., Mao, M. (2013). The Relationship Between Trees and Human Health: Evidence from the Spread of the EAB. American Journal of Preventative Medicine. 44(2): 139-45. http://californiareleaf.org/trees-in-the-news/the-relationship-between-trees-human-health

- Dunn, A.L., Trivedi, M.H., Kampert, J.B., Clark, C.G., and Chambliss, H.O., 2005. Exercise Treatment for Depression. Efficacy and Dose Response. American Journal of Preventative Medicine, 28(1):1-8

- Hanson, P., Matt, F., Bowyer, J., Bratkovich, S., Fernholz, K., owe, J., Groot, H., Pepke, E. (2016) The Human Health and Social Benefits of Urban Forests. Dovetail Partners Inc. (1 MB PDF, 12 pages)

- Kalpan, R., Kaplan, S. (1989) The experience of nature: A psychological perspective. New York: Cambridge University Press.'

- Laibstain, S.E. and Carek S.M., 2011. Exercise for the Treatment of Depression and Anxiety. Int'l. J. Psychiatry in Medicine, Vol. 41(1) 15-28, Medical University of South Carolina, Charleston.

- Lee, J., Park, B. J., Tsunetsugu, Y., Kawaga, T., Miyazaki, Y. (2009). Restorative effects of viewing real forest landscapes, based on a comparison with urban landscapes. Scandinavian Journal of Forest Research. 24(3): 227-234. http://www.tandfonline.com/doi/abs/10.1080/02827580902903341#preview

- Li, Q. (2010). Effect of forest bathing trips on human immune function. Environmental Health and Preventative Medicine. 15(1): 9-17. http://wwwncbi.nlm.nih.gov/pmc/articles/PMC2793341/

- Li, Q., Kawada, T. (undated but probably 2010). Healthy forest parks make healthy people: Forest environments enhance human immune function. Department of Hygiene and Public Health, Nippon Medical School, Tokyo, Japan. http://www.hphpcentral.com/wp-content/uploads/2010/09/5000-paper-by-Qing-Li2-2-pdf

- Maas, J., Verheij, R., Groenewegan, P., de Vries, S., Spreeuwenberg, P. (2006) Greenspace, urbanity, and health: how strong is the relation? Journal of Epidemiology and Community Health. 60(7): 587-592. http://www.ncbi.nih.gov/pmc/articles/PMC2566234/. Carek, P.J.

- O'Neal, H.A., Dunn, A.L., and Martinsen, E.W., 2000. Depression and exercise. International Journal of Sport Psychology, 31(2), 110-135

- Robinton, C., December 11 2015. Stay Happy and Healthy: Got Fishing. Fishing for mental health and well-being. https://www.fix.com/blog/fishing-for-wellness/

- System: Judicial Recognition At Last. Washington Journal of Environmental Law & Policy

- Wood, M.C., and Knight P.H., 2015. Atmospheric Recovery Litigation: Making The Fossil Fuel Industry Pay To Restore A Viable Climate System, Environmental Law & Policy

- Wood, M.C., and Woodward, C.W., 2016. Atmospheric Trust Litigation and the Constitutional Right to A Healthy Climate

Mitigation and Adaptation Strategies: Summary

The response to climate change involves two components – mitigation and adaptation. The application of which strategy or combination of strategies to use will differ for each of the five core areas - Energy, Transportation, Natural Systems, Human Health and Land Use. While mitigation aims to reduce the magnitude of climate change, adaptation focus on reducing vulnerability to the effects of climate change. Both techniques work together to improve human and ecosystem resilience to the impacts of climate change. Mitigation and adaptation involve different techniques, but compliment and supplement each other. In some circumstances, a combination of the two is necessary. Some of the recommendations for implementing mitigation and adaptation strategies include:

- Establish a Carbon Tax as recommended by the IPCC
- Reduce the impermeable surfaces; provide both positive and negative incentives
- Increase albedo of non-reflective, dark roofs and black paved surfaces - make them a lighter color, preferably white
- When planting trees or shrubs, select only native species when possible
- Plant trees - Cuyahoga County currently provides $950 000 of funding a year, until 2024, to plant trees to replace lost canopy
- Revise building codes to include:
  - Increased amount of permeable surfaces in parking lots and roads
  - Water conservation measures within and outside of buildings
  - Installation of solar panels on buildings, establishing incentives and modifying building codes to promote their use
  - No clear-cutting of trees for developments
- Use CO_2 absorbing concrete in construction projects.

Table 2. Mitigation and adaptation strategies that can reduce emissions and the effects of climate change impacts on human health.

MITIGATION Actions to reduce Greenhouse Gas emissions:
- Promote energy efficiency and conservation - Subsidize and use renewable energy - Use efficient vehicles - Biking, walking, using ride share and taking public transportation - Reduce and divert solid waste - Promote the use of CO_2 absorbing concrete - Plant more trees
ADAPTATION Reduce impacts of climate change:
- Conduct vulnerability assessments - Continue storm water management plans and increase riparian setback zoning - Utility burial for street and traffic lighting - Plan for emergency response to incorporate climate impacts - Plant indigenous trees - Mandate permeable pavements to reduce tar and concrete - Follow MetroHealth's Eco protocols; Healthy Cleveland initiative.
MITIGATION AND ADAPTATION **A mixture of methods to reduce both emissions and impacts:**
- Implement green zoning and land use codes - Promote local food and urban agriculture - Promote and enforce green infrastructure - Start composting - Plant trees - Create green roofs

Table 2 data from CCCCAP and modified from Climate Action for Health: Integrating Public Health into Climate Action Planning, California Department of Public Health, February 2012.

The CCCCAP document includes a Vulnerability Assessment Tool created as a part of the risk factor for natural hazards. This tool is an interactive online map that can be used to identify communities most vulnerable to the effects of climate change. These effects include flooding, extreme heat, foodborne illness, allergens and arboviruses.

The Vulnerability Assessment Tool maps social and physical factors to show the vulnerability of all communities in Cuyahoga County. This tool can be accessed at:
Climate Change Vulnerability Assessment – Cuyahoga County Planning Commission

Climate-Related Hazards

Due to regional context, Cuyahoga County and its residents are not directly subjected to some commonly associated climate risk factors, such as rising sea level, coastal flooding, hurricanes and severe tornadoes. Local climate risks include extreme precipitation events (both rain and snow) and extreme temperatures.

In 2017, the Cuyahoga County Office of Emergency Management (OEM) released its "2016-2022 All Hazards Mitigation Plan". The Plan currently identifies several "Medium Risk" climate-related hazards, each

of which can be expected to worsen over time.

Risks factors include health related emergencies (including vector-borne diseases), flooding, temperature extremes and severe winter weather, among others.

Table 3 shows Risk Factors, calculated for each hazard, and provides a combination of ratings for Probability, Impact, Spatial Extent, Warning Time, and Duration. Each rating is scored 1- 4 in varying degrees of risk and includes a weighted factor.

Although the All Hazards Mitigation Plan is an environmental hazard plan, and not a climate mitigation plan, it still contains components, which are directly applicable for climate change adaption strategies (CCCCAP Table 4.1).

Table 3. Risk Factors for natural hazards in Cuyahoga County.

	Natural Hazards	Probability		Impact		Spatial Extent		Warning Time		Duration		RF Factor
1	Health Related Emergencies	2	0.6	3	0.9	4	0.8	1	0.1	4	0.4	**2.8**
2	Flooding	4	1.2	2	0.6	1	0.2	4	0.4	3	0.3	**2.7**
3	Temperature Extremes	4	1.2	1	0.3	4	0.8	1	0.1	3	0.3	**2.7**
4	Severe Winter Weather	4	1.2	2	0.6	3	0.6	1	0.1	1	0.1	**2.6**
5	Earthquake	2	0.6	2	0.6	4	0.8	4	0.4	2	0.2	**2.6**
6	Severe Thunderstorms	4	1.2	2	0.6	2	0.4	2	0.2	2	0.2	**2.6**
7	Tornadoes	3	0.9	2	0.6	1	0.2	4	0.4	2	0.2	**2.3**
8	Drought	2	0.6	1	0.3	4	0.8	1	0.1	4	0.4	**2.2**

Table 3 reproduced from CCCCAP document (presented as Table 4.1). Risk Factor = RF.

CIVIC EDUCATION

Communities should develop course content with implementation strategies, in line with the six focus areas of climate impacts on human health. These new resources will aid workshops and training events, incorporating the basic concepts and definitions relating to climate change. They should also include mitigation and adaptation techniques applicable to human health (Anderson, 2012, Boakye, 2015, Monroe et al., 2017, National Centre for Science Education (NCSE), 2019).

IMPLEMENTATION OF THE CLIMATE MITIGATION AND ADAPTATION STRATEGY

The implementation of the strategies provided in this document will require a profound change in governmental, societal, and individual thinking. People will need to rethink certain lifestyles if they want to lessen the severe impacts of climate change. These actions would collectively help protect the health of the ecosystem on which human health is absolutely reliant. These co-benefits are listed along with the most suitable mitigation and adaptation strategies in Table 4.

Table 4. Summary of the Mitigation and Adaptation Strategy		
STRATEGY TO REDUCE GHG EMISSIONS FROM CCCCAP	**MITIGATION AND ADAPTATION RECOMMENDATIONS**	**POTENTIAL HUMAN AND ECOSYSTEM HEALTH BENEFITS**
REDUCE VEHICLE MILES TRAVELED	• Ride share • Increase use of RTA • Bicycle use • Electric and hybrid vehicles	• Increased physical activity • Reduced chronic diseases • Improved mental health • Reduced air pollution • Reduced water and soil contamination
REDUCE EMISSIONS THROUGH LAND USE CHANGE	• Install solar panels • Connect green areas/trails • Reduce use of plastics	• Increased physical activity • Reduced chronic diseases • Increased local access to essential services (affordable housing, jobs, amenities) • Enhanced safety • Improved water quality • Improved terrestrial and aquatic biodiversity • Reduced endocrine-related diseases • Increased urban and habitat resilience • Improved mental health
REDUCE RESIDENTIAL BUILDING ENERGY USE	• Install solar panels on roofs • White roofs and paving • Greening Roofs and installing vertical gardens	• Reduced household energy costs • Promote healthy homes • Create local green jobs • Promote cooler communities (lower albedo) • Improved mental health
URBAN GREENING LAND USE CHANGE	• Plant more trees - Urban streets, vacant land, parks, schools, homes. • Increase permeable surfaces	• Reduced temperature and urban heat island effect • Reduced air pollution • Reduced noise • Enhanced safety by lowering heat-related crime • Improved water quality • Reduced flooding & erosion • Improved biodiversity • Reduced invasive species • Reduced impermeable surfaces; roads, parking • Reduced vectors and associated diseases • Improved mental health • Reduced anxiety and sense of helplessness
REDUCE ENERGY INTENSITY IN LOCAL FOOD SYSTEMS	• Reduce food miles • Promote local agriculture • Encourage less red meat consumption • Expand farmers' markets and community gardens • Land use change — increase urban and backyard agriculture	• Increased access to quality, healthy, fresh foods • Reduced cardiovascular disease from cooking with and eating saturated fats • Reduced air pollution • Increased local social cohesion • Increased resilience • Increased food micronutrients • Reduced transportation carbon footprint • Reduced pesticide, herbicide and fertilizer use • Reduced imported food consumption

Table 4 modified from Climate Action for Health: Integrating Public Health into Climate Action Planning, California Department of Public Health, February 2012.

MITIGATION AND ADAPTATION STRATEGIES TO IMPROVE RESILIENCE

The strategies provided in this document will help enhance:

- Ecosystem health by watershed protection
- Management of viral hosts
- Achievement of near-zero chemical exposure
- Planting trees; minimum of 500,000 by 2050
- Increased exercise; create and improve opportunities for people to be outdoors and increase physical activity and mental well-being

Trees play a central part in mitigation and adaptation for climate change. They sequester carbon, reduce storm water runoff, help cool urban areas and provide free stress-release to help lessen concerns related to mental health and anxiety.

ACTION ITEMS FOR TREES:
- Expand and promote better adoption of storm water fee credit
- Integrate precipitation projections into Emergency Operations Plan for Ohio
- Establish tree canopy goals within each municipality throughout Cuyahoga County
- Create a County-wide tree fund, prioritizing planting in areas that are most vulnerable, per Cuyahoga County Planning Commission's Vulnerability Assessment Tool
- Promote the Cuyahoga County Planning Commission's Greenprint Guidebook recommendations
- Implement the recommendations of the Cuyahoga Greenways Plan

Additional information on this topic is provided in Appendix 2. Ecology and Trees.

POLICY FOR MITIGATION AND ADAPTATION

Policies advocated by the County includes the rapid development and efficient deployment of clean energy and the creation of a county-wide green bank to finance clean energy and renewable energy sources. The bank would advocate specific policies for each of the five CCCCAP areas of Energy, Transportation, Natural Systems, Human Health and Land Use.

A Policy for Human Health would need to address controversial issues such as levels of benzene and industrial chemicals in the environment, the current levels of airborne particulate matter, and whether to incorporate climate change as a component of human health practice. It would also include a single-use plastics policy with consideration for an overarching total ban on single-use plastics if deemed necessary in the future.

On the national scale, there is litigation currently underway, which deals with the Public Trust Doctrine and its applicability for the National Resources and Atmospheric Law (Blumm and Wood, 2013). The Public Trust Doctrine states that citizens have inalienable rights to a healthy environment and that government has a sovereign duty to protect crucial natural resources for the benefit of present and future generations (Wood and Knight, 2015). A lawsuit brought by youth plaintiffs claims their constitutional right to a healthy environment is being violated by the federal government's fossil fuel policy. They suggest alternative mechanisms to reduce emissions, such as making producers of coal, oil, gas, and other fossil fuels, responsible for their emissions, which contribute to climate change. (Coghill, et al., 2012; Wood and Woodworth, 2016).

Monitor Progress and Make Changes
Quarterly management meetings will be held by members of the five management areas; Energy, Water, Transportation, Human Health and Land Use. These groups will review and monitor progress on adaptation and mitigation strategies. Annual total emissions for the County will be obtained from the Cuyahoga County Department of Sustainability.

These meetings will also allow for flexibility in assessing how well various aspects of the Mitigation and Adaptation Strategies are developing and if any changes or additions are required. Discussion will be particularity pertinent when addressing topics like extreme weather events, increased temperatures and their effect on violence levels, monitoring vector-borne diseases, water quality, etc. Changes in tree canopy and ecosystem health will also be assessed and evaluated at these meetings.

Table 5. Assessing and measuring climate impacts with recommended actions

| CLIMATE IMPACTS TO BE ASSESSED	METRIC (E.G. HOW TO MEASURE PROGRESS)	ACTION TO BE TAKEN
EXTREME WEATHER EVENTS		
• Carbon and other GHG emissions • Impact of increased temperatures on human health and violence levels • Heat island effect	• NOACA audits • NOAA daily temperature data • Number of people requiring emergency health care, and police records of violence • Roof temperatures • Conversion of impermeable surfaces	• Policies to reduce emissions • Increased presence of police, first responders, and other health care providers • Roof gardens and light colored roofs • Reduction in hardscape
OTHER CLIMATE CHANGE IMPACTS		
• Vector-borne diseases	• Monitor mosquito and tick activity • Document new arthropod or vectors	• Adjust treatment of wetlands • Increase tick control
• Water quality	• Monitor rivers and beaches for pathogens and microcystin	• Identify sources • Close beaches • Reduce nutrients used by algae
• Allergens, soot, pollen and fungal spores	• NOACA ongoing air monitoring program • Cleveland Dept. of Public Health Division of Air Quality	• Policy to reduce particulate matter • Management of invasive plant and fungal species
• Mental health and well-being	• Potential increase in suicide • County-wide surveys of how people are feeling regarding climate change	• Clinical interventions (MetroHealth, Community Trauma Institute, other hospital groups) • Activities to ameliorate depression (walking, gardening, etc.)
• Changes in tree canopy	• Aerial, Google and satellite surveys • Monitor tree felling at time of development (community development/subdivision restrictions) • Land Conservancies	• Implement policies that prevent tree loss during development • Encourage households, businesses and industries to plant trees
• Ecosystems and ecosystem services	• Biodiversity • Monitor soil and habitat impacts	• Increase in invasive plant and animal species • Improve soil quality • Prevent destruction of habitats
• Lack of public awareness and support	• Surveys to determine if opinions are changing to support climate change measures	• Conduct educational workshops and distribute materials appropriate to audience • Allow public to provide input on local policies that change habit

Table 5 created by R.F. Brand
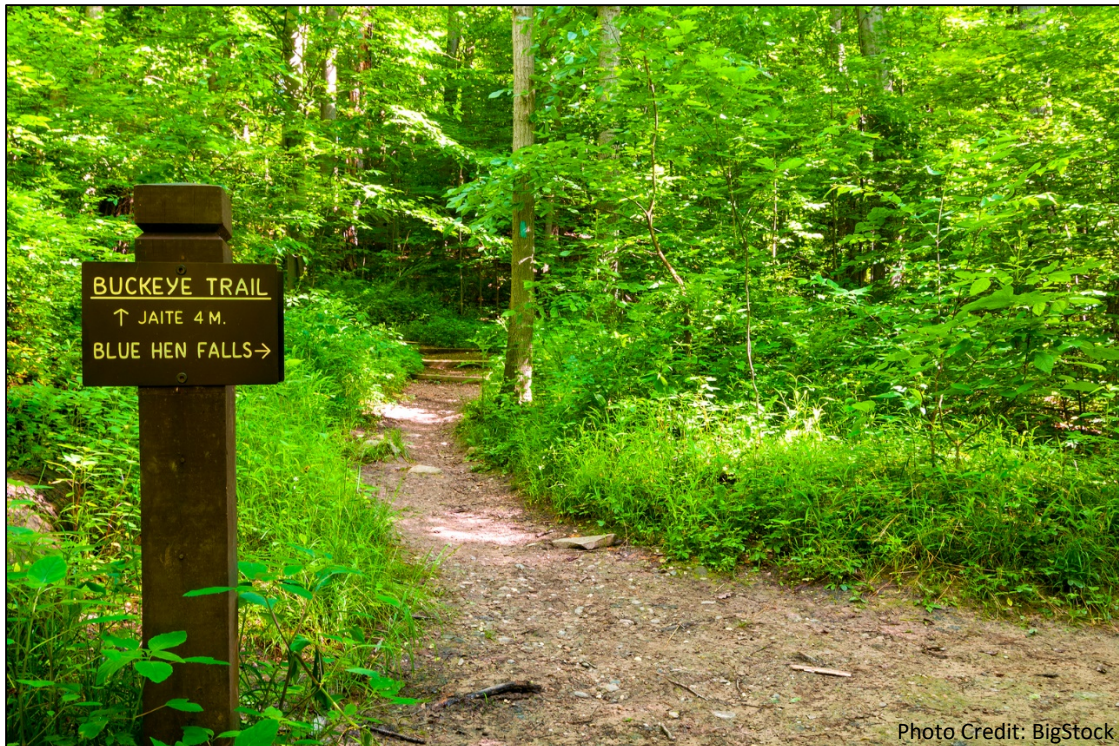
Relieve climate anxiety by exercising, going for a walk, enjoying the trees, and the outdoors.

IMPLEMENTING EDUCATION

Providing education about the impacts of climate change on human health may be the most significant strategy in the implementation of all mitigation and adaptation measures. The effectiveness of workshops and other educational methods, along with the distribution of impactful materials, can be evaluated and updated, based on trends and the extent of climate change impacts being experienced. Evaluation will also allow for the monitoring and update of the mitigation and adaptation strategies to ensure they are achieving their targeted goals.

CONCLUSION

As rising CO_2 levels and increases in temperature continue in the future, the implementation of successful mitigation and adaptation measures is urgently necessary to help reduce greenhouse gas emissions, improve human and ecosystem resilience and reduce the negative effects of climate change. Strong leadership is required to create and implement appropriate policies that will make a difference. Financial commitment on many levels must occur if we are to reduce emissions and ensure the global temperature does not continue to rise by more than 1.5°C by the Year 2030. If nothing is done, the disastrous consequences of climate change will remain unchecked.

The CCCCAP document lays out specific recommendations for action, while the Mitigation and Adaptation Strategies provide additional details and potential human and ecosystem health benefits (as provided in Table 4). These documents assess and measure climate impacts, while laying out a list of recommended actions (as described in Table 5).

The national anti-littering campaigns that began in the 1950's provide a model for the use of television, radio and now, social media, for the successful promotion of environmental-friendly climate change and energy conservation programs. To address issues like human overconsumption, we must first acknowledge that a shift in the public's thought process needs to occur. A fundamental change in the way consumption is rationalized must include specifics on what is being consumed and how it is produced. Any updated campaigns must be mindful to promote logical and easily identifiable methods the public can support as we shift to more ecologically responsible ways of thinking and acting. Education and policy implementation are two essential components to the process of slowing and overcoming the impacts of climate change, which arguably along with nuclear war, remains one of the greatest threats to U.S. national security (IPCC, 2019; Sanders, 2016) and ecosystem biodiversity, human health and well-being.

Appendix 1. Climate Change 101 - Key Concepts

KEY CONCEPTS

1. **The difference between Global Warming and Climate Change.**
2. **What causes climate change? Why are CO_2 levels rising?**
3. **What is the difference between weather and climate?**
4. **What are Greenhouse Gases?**
5. **What is the atmospheric composition of gases and Greenhouse Gases?**
6. **Why will the effect of current atmospheric CO_2 levels continue for thousands of years?**
7. **What is the Greenhouse Effect?**
8. **What are the effects of climate change on Earth?**
9. **What are ecosystems?**
10. **What are ecosystem services?**
11. **Why is it important to protect ecosystems (trees, biodiversity and water)?**
12. **What can we do to reduce climate change?**
13. **What is climate mitigation? What are the mitigation strategies?**
14. **What is climate adaptation? What are adaptation strategies?**
15. **What are the projected global and U.S. costs of climate change?**
16. **What are the types of extreme weather events and how have they impacted the U.S.?**
17. **Do we have legal, moral and ethical obligations to reduce climate change?**

1. The difference between Global Warming and Climate Change.

Global Warming and Climate Change - are they the same, and which term should I use? **"Global Warming"** is the rise of global temperatures due to the increase of greenhouse gases added to the atmosphere, whereas **"climate change"** refers to the increased changes of the measures of climate over a long period (USGS.gov).

The difference is explained by David Herring and Rebecca Lindsey on the NOAA website, Climate.gov: "Both phrases can have slightly different meanings in different contexts, but these days, *global warming* generally refers to the long-term increase in global average temperature as a result of human

activity. Climate change is a much broader term that covers changes in multiple parts of the climate system, from temperature to precipitation to wind patterns. Climate change can be local, regional, or global, and it can have natural or human causes. Global warming is a type of climate change; however, not all climate change is global warming." Whichever term is used, global warming and climate change are linked by excessive, increasing energy build-up in the atmosphere.

How and why has the confusion occurred between the two terms? Since the 19th Century, scientists have hypothesized that human-induced burning of industrial chemicals and fossil fuels has modified the climate and increased the average temperature despite the natural processes cooling the climate.

Starting in the mid-1950's and augmented by Wallace Broecker et al., in the mid 1970's, the mounting evidence has unequivocally shown that global warming was dominating over cooling, with human activity being the predominant cause. Current temperature increase due to global warming is unlike any previous episodes Earth has experienced since the Pliocene Epoch, between 2.6 and 5.3 million years ago.

References:
Global Warming FAQ. Global warming frequently asked questions | NOAA Climate.gov.
Global Warming vs. Climate Change. (NASA - What's in a Name? Global Warming vs. Climate Change

2. What causes climate change? Why are CO_2 levels rising?

Climate change is driven by rising levels of atmospheric CO_2 caused by anthropogenic (human created) burning of fossil fuels (coal, oil and natural gas). A rapid increase has been recorded in the last 50 years, but it seems to have begun with industrial processes during the Industrial Revolution that released CO_2, now augmented by automobile exhaust emissions. An exponential increase in human

population, ±1.6 billion in 1900 to ±7.9 billion in December 2021, with increased consumption and vehicle miles traveled, augmented atmospheric CO_2. Previously, CO_2 levels were the result of natural processes (volcanoes eruptions, wildfires, decomposing plants, etc.). Currently CO_2 levels are the highest ever recorded. They have been as high as 7000 ppm in the Cambrian era (550 million years ago). Data from NOAA (Figure 1) shows CO_2 levels for December 2021 at 416.71 ppm and February 2019 at 414.83 ppm, while 2007 levels were 404.83 ppm.
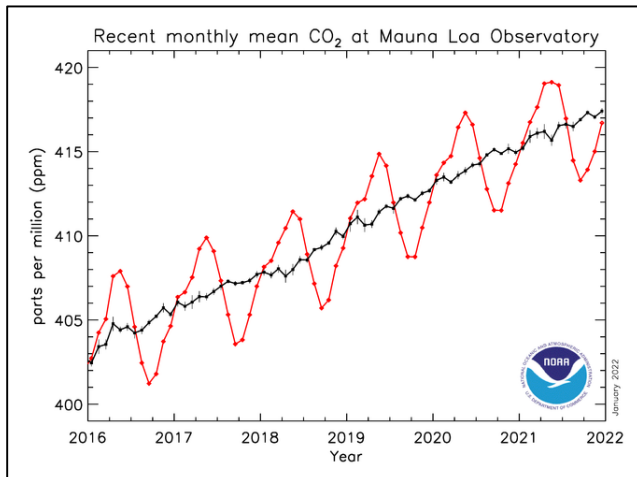

Figure 1. Carbon Dioxide levels from 2016 to 2021

On the graph, the red line shows the monthly mean CO_2 values, centered in the middle of each month. The black is the same after correction for the average seasonal cycle. Since 2015, the mean CO_2 levels have steadily increased from 400 ppm to 416 ppm.

3. What is the difference between weather and climate?

Weather occurs every day, and is happening now, all over the planet. It includes fog, rain, snow, cloud cover, tornadoes, winds and the effects on waves and the ocean. It is what we can see, feel and perceive directly; how hot or cold it will be today, tomorrow or the next day. Weather forecasters use meteorological data to predict the statistical probability of what the weather may be in the near future.

Climate is what has happened historically, in the past, and what models may predict for the future, globally. It includes long-term changes and fluctuations in sea levels, concentrations of atmospheric gases including CO_2 and other greenhouse gases, the extent and thickness of ice sheets, the effects of volcanism and vegetation composition. All of these parameters are measured and used to model and predict changes to climate according to how these forces combine to modify ecosystems and the conditions for life on Earth. Ice cores, marine and freshwater sediment cores, soil cores, and tree cores are used to determine palaeoclimates, vegetation composition, plant species and atmospheric CO_2 levels in the past.
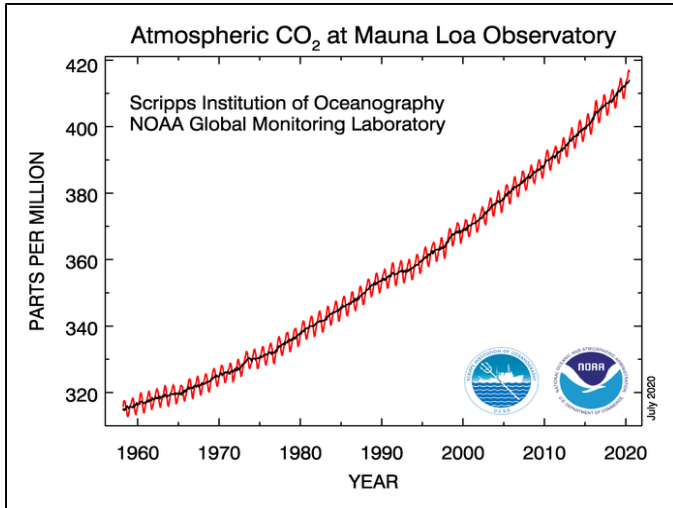
4. What are Greenhouse Gases?

There are four naturally occurring Greenhouse Gases (GHG) and two main anthropogenic (man-made) GHGs. The human-made gases are Chlorofluorocarbons (CFCs) and Hydrofluorocarbons (including HCFCs and HFCs). The four naturally occurring GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and water (H_2O) as water vapor. The manufacturing of CFCs stopped in the mid 1980's due to the damage caused to the Ozone layer. Hydrofluorocarbon (HFC) was produced to replace CFCs. All GHGs absorb and emit infrared radiation. Infrared radiation extends from the red edge of the visible spectrum at 700 nanometers (nm) to 1 millimeter (mm). GHGs do not interact with sunlight in the visible spectrum (the human eye sees wavelengths from 380 to 740 nanometers). Nitrogen, Oxygen and Argon combined equal 99% of the gas atmosphere, however, none of these gases absorb infrared radiation and are not GHGs.

5. What is the atmospheric composition of gases and Greenhouse Gases (GHGs)?

By volume, dry air contains 78.09% nitrogen, 20.98% oxygen, 0.93% argon and 0.04% carbon dioxide (CO_2). Carbon dioxide levels for December 2021, ≥416.71 ppm = 0.0416%), with all the other gases combined equaling less than 1 percentage (Scripps CO_2 Program). The four main GHGs have very low percentages in the atmosphere but have a huge effect on temperature by absorbing infrared radiation. Clouds (as water vapor) are strong absorbers and emitters of infrared radiation. This is why it becomes colder at night at higher elevations if there are no clouds to hold and emit infrared radiation.

6. Why will the effect of current atmospheric CO_2 levels continue for thousands of years?

Even if all emissions stopped today, the existing amount of CO_2 in the atmosphere will take time to be sequestrated (absorbed) and processed by the natural oceanic chemical cycles and terrestrial ecosystem processes of the earth.

Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Global Monitoring Laboratory

Natural processes include terrestrial routes (soil formation and photosynthesis) and oceanic chemical cycles. Carbon is absorbed to form the two main carbonate rocks - limestone and dolomite.

land. The remainder is reflected by the atmosphere or clouds. At night the land cools by radiating the infrared radiation back into space, however, some of the radiation is trapped or reflected by water vapor and other Greenhouse Gases. It is this process which keeps the earth's surface warm and enables life on Earth to exist.

8. What are the effects of climate change and rising CO_2 on Earth?

The effects of climate change will continue to increase both terrestrial and ocean temperatures. Temperature warming is triggering acidification of the oceans, bleaching of coral reefs, icecap melting and sea level rise. Climate change is providing increased energy available for storms, resulting in more extreme weather events with greater intensity. Rising CO_2 levels are also vastly reducing the productivity of ecosystems and biodiversity. Major climate alterations and loss of habitat are occurring with excessive loss of plants and animal life, ultimately causing the potential mass extinction of entire animal and plant species and genera.

What is the Greenhouse Gas Effect?
The illustration of Cleveland shows a portion of the incoming and outgoing solar radiation (yellow arrows), reflected by the atmosphere and clouds. The Earth's surface absorbs infrared radiation (red arrows) at a rate of about 168 watts per meter^2. The energy is converted back into infrared radiation and re-emitted to the atmosphere. Here, some of it is absorbed by Greenhouse Gases (CO_2, Methane) and reflected back to the earth adding to warming. The direct effect is to warm the troposphere and the Earth's surface, which gains more heat and results in more infrared radiation again being emitted. This is the Greenhouse Effect - continuous reflection, absorption and re-reflection of infrared radiation with the cumulative effect of heating the Earth's surface and atmosphere.

Image modified by Hannah Kiraly, Cuyahoga County Planning Commission.

7. What is the Greenhouse Effect?

The Greenhouse effect is the increased heating of the planet due to the reflection and absorption of infrared radiation by Greenhouse Gases and water vapor molecules in the atmosphere. Of the total incoming solar radiation, 51% is absorbed by the oceans and

9. What are ecosystems?

The Merriam-Webster dictionary defines an ecosystem as "the complex of a community of organisms and its environment, functioning as an ecological unit". Ecosystems include aquatic, terrestrial and atmospheric systems.

A more detailed definition identifies an ecosystem as "Any unit that includes all of the organisms (i.e. the community) in a given area interacting with the physical environment so that the flow of energy leads to clearly defined trophic (feeding) structure, biotic diversity, and material cycles (i.e. exchange of materials between living and nonliving parts) within the system" (Odum 1972).

An ecosystem is considered to be a community made up of living organisms (biotic) and non-living (abiotic) components. Biotic components include plants, animals, fungi, bacteria and soil microbes. Abiotic components include moisture, altitude, temperature, and inorganic (mineral) soil composition. Other measureable ecological parameters include atmospheric pressure, wind velocity, solar radiation, cloud coverage, dissolved oxygen in water, albedo, and terrestrial and ocean temperatures.

10. What are ecosystem services?

Ecosystem services are the collective benefits humans gain from naturally functioning ecosystems. These benefits are free. Examples include providing clean drinking water, decomposing wastes, and insect pollination of all flowering plants. The term "environmental services" was introduced in a 1970 report; 'Study of Critical Environmental Problems' (SCEP, 1970). The report listed ecosystem services including insect pollination, water purification, (wetlands, bogs), climate regulation, erosion and flood control (trees, vegetation, and grasses). In the following years, variations of the term were used, but eventually "ecosystem services" became the standard in scientific literature (Ehrlich and Ehrlich, 1981)

11. Why is it important to protect ecosystems (specifically trees, biodiversity and water)?

The biotic and abiotic components of all ecosystems interact through nutrient cycling and energy flow.

Impairment or fragmentation of ecosystems cause imbalance, reducing ecosystem services, decreasing productivity, and increasing diseases and invasive species.

It is important to protect trees, as they sequester CO_2 during photosynthesis, reduce storm water runoff and erosion, lower ambient temperature, reduce evaporation, and increase soil microbes, soil nutrients and soil health. Trees also maintain water quality by reducing sediment load and shading streams. Trees function to maintain or increase dissolved oxygen in stream water. This is vital for supporting healthy, thriving and biodiverse aquatic life forms including fish, amphibians and reptiles. Less diverse urban plant and animal communities have reduced resilience, resulting in a lower survivability rate, with a poor response to environmental changes and natural disasters. Life on Earth depends on healthy, functioning ecosystems. This includes humans, which are only one of the estimated 8.7 million species of living organisms inhabiting Earth.

12. What can we do to reduce climate change?

Climate change can be reduced by enacting mitigation and adaptation strategies. Adaptation strategies limit our human vulnerability to the effects of climate change. Mitigation measures help reduce the effects of climate change and include things like walking instead of driving, eating less red meat, planting lots of trees, using public transport, buying an electric or hybrid vehicle which has reduced or no emissions, better insulating homes, installing solar panels and hot water heaters, recycling and reducing consumption.

13. What is climate mitigation? What are mitigation strategies?

Climate mitigation aims at reducing the magnitude of climate change. Mitigation strategies aim to reduce fossil fuel emissions and offset Greenhouse Gases (GHGs) using geoengineering (industrial processes) augmented by natural processes such as planting trees (reducing deforestation) to sequestrate (hold) Carbon.

14. What is climate adaptation? What are adaptation strategies?

Climate adaptation is defined as improving human

and infrastructure resilience to the effects of climate change. Adaptation measures are not applicable to natural ecosystems. They are only applicable to the anthropogenic or built-environment of cities, urban areas, roads, farms and mining operations. An adaptation strategy would look to reduce impermeable surfaces (roads, parking lots), which ultimately reduces storm water runoff, flooding and the heat island effect. Planting trees is an example of both an adaptation and mitigation strategy.

15. What are the projected global and U.S. costs of climate change?

The United Nations Framework Convention on Climate Change (UNFCCC) estimates that by the year 2030, global annual costs of climate change will be between $49 to $171 billion. The World Bank estimates annual costs by 2050 to be $75-$100 billion.

In 2018, there were 14 separate billion-dollar weather and climate disaster events across the United States, with a total cost of $91 billion. The total cost over the years of 2016 - 2018 exceeds $450 billion [Sourced from NOAA's (National Center for Environmental Information) (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2019)].

16. What are the types of extreme weather events and how have they impacted the U.S.?

Since 2000, the top 10 disasters include 8 hurricanes and 2 droughts with Hurricane Katrina (August 25-30, 2015) killing 1,833 people and causing damages of approximately $148 billion (Center for Climate and Energy Solutions, 2018). Estimated costs for extreme weather events in 2018 were $155 billion, ranking it 4th among the greatest billion-dollar disaster years, following 2011, 2016 and 2017 (NOAA's National Center for Environmental Information). After hurricanes, California wildfires ranked 2nd as the most costly extreme weather events, with a total of 8,527 fires burning an area of 1,893,913 acres during 2018. These fires killed at least 86 people and caused building and infrastructure damage of $3.5 billion (2018 National Large Incident Year-to-Date Report. National Interagency Fire Center. November 9th 2018. Retrieved, November 9th 2018).

Extreme weather events responsible for the most deaths and billion dollar costs include hurricanes, wildfires, extreme heat, extreme precipitation, tornadoes and drought. The National Climate Assessment finds that the strength and number of extreme weather events, including major hurricanes, heat waves and heavy downpours, has increased in the United States since 2000.

17. Do we have legal, moral and ethical obligations to reduce climate change effects?

Yes. The Public Trust Principal states that citizens have inalienable rights to a healthy environment and that government has a sovereign duty to protect crucial natural resources for the benefit of present and future generations (Wood and Knight, 2015; Wood and Woodward 2016). We have a moral and ethical obligation to reduce the effects of climate change. The data since the mid-1950's shows the increase in CO_2 is due to human industrial activity. We have the technical capability to reduce emissions and reliance on fossil fuels. The problem is a moral one, which requires political will and public support to be addressed effectively.

References:
- Allen, H., and Hoekstra T.W., 1992. Toward a Unified Ecology, Colombia University Press, New York
- Christian R.R., 2009. Concepts of Ecosystem, Level and Scale in: ECOLOGY, Vol. I., Encyclopedia of Life Support Systems (EOLSS), UNESCO.
- Ehrlich, P.R., and A. Ehrlich, 1981. Extinction: The Causes and Consequences of the Disappearance of Species. Random House, New York. 305pp.
- Odum, 1972. Fundamentals of Ecology, 1971. W. B. Saunders Company, Philadelphia
- SCEP and Ehrlich and Ehrlich from 'Ecosystem Services' Wikipedia, 11 March 2019, at 17:19 (UTC)
- Study of Critical Environmental Problems (SCEP) 1970. Man's Impact on the Global Environment. MIT Press, Cambridge. 319pp.
- Wood, M.C., and Knight P.H., 2015. Atmospheric Recovery Litigation: Making The Fossil Fuel Industry Pay To Restore A Viable Climate System, Environmental Law, Vol. 45:259
- Wood, M.C., and Woodward, C.W., 2016. Atmospheric Trust Litigation and the Constitutional Right to a Healthy Climate System: Judicial Recognition at Last. Washington Journal of Environmental Law & Policy.
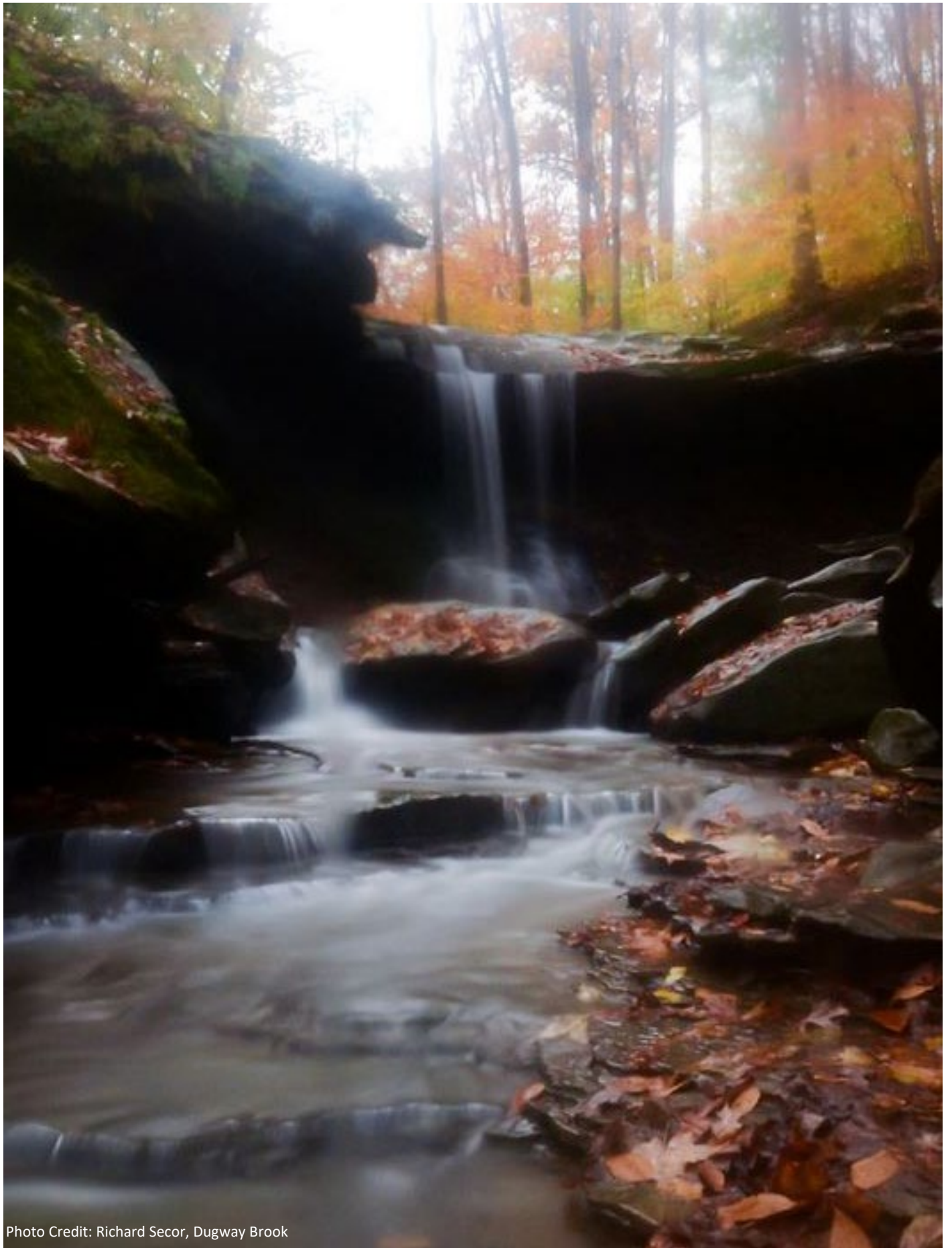
Photo Credit: Richard Secor, Dugway Brook

Appendix 2. Ecology and Trees: Ecosystems, Ecosystem Services and Biodiversity

Climate change will continue to impact ecosystems, ecosystem services, and biodiversity in Cuyahoga County. With this in mind, the following topics are addressed in this appendix:

1. **Watersheds - Rivers, Streams and Lake Erie**
2. **Vegetation – Plant Biodiversity**
3. **Human Health and Urban Ecology**
4. **Urban Trees**
5. **Lawns**
6. **Environmental Management and Ecological Restoration**

The word ecology is derived from the Greek words 'oikos', meaning 'house' or 'environment' and 'ology' meaning the 'study of'. Ecology is a branch of biology that studies living organisms and their interaction with the environment. Ecologists may study living organisms and non-living materials as small as microscopic bacteria or as large as whole-earth systems. The term was created by British Ecologist Ray Clapham in the 1930's and was developed further by Arthur Tansley in 1935 (Raffaelli and Frid, 2010). The current understanding of 'ecosystem' includes all organisms which regulate the flow of energy and matter through an environment. Ecosystem processes include primary production, nutrient cycling and the regulation of energy flow and movement of matter through an environment. Biological diversity, or biodiversity, includes all living organisms, their genes, and ecosystems.

Ecosystems can be terrestrial, aquatic, atmospheric, or a combination of more than one and can vary in size from one plant in a terrarium, to the entire Earth. In the mid-1960's, James Lovelock put forward the 'Gaia Hypothesis' which considered the entire Earth's organisms and environment, as a complete, self-regulating functioning ecosystem. Every ecosystem is composed of interactive organic and inorganic components (Lovelock, 1972, 1995). The Gaia Principle is a useful explanation that helps one understand ecosystems (Schwartzman, 2002). Over the years, the Gaia Principle has evolved to take on a more holistic view which includes not only the living (biotic) and nonliving (abiotic) factors, but also includes the inexorable link between human actions and the effects on ecosystems (Raffaelli, D.G., and

Frid C.L.J., 2010). It is from this viewpoint, that we understand how sociology (human activity) and ecology (ecosystems) can be combined in the context of climate change and its impacts on human and ecosystem health. It also recognizes that the functions ecosystems provide are vital to all life, and that healthy ecosystems should not be a privilege, but a necessity and a right, determined by ethical principles (Barnhill, D.L., and Gottlieb R.S., 2010), found under the Public Trust Doctrine and Natural Resources Law (Blumm M.C., 2013, Coghill, et al., 2010).

In 2018, the members of the Lake Erie Allegheny Partnership for Biodiversity (LEAP) released a conservation plan titled "Regional Biodiversity Vision". This work is significant because it is the first comprehensive analysis of climate change impacts on the environment within the "regional biodiversity". The LEAP region encompasses northeast Ohio (including Cuyahoga County), northwest Pennsylvania and western New York. LEAP's plan provides management strategies and suggestions to help protect biodiversity and ecosystems based on the most recent data (US Forestry, NOAA, NIACS, and USGS Great Lakes Region). The chief threat to biodiversity loss and ecosystem destruction is human development and the associated effects of climate change. Suggestions from the LEAP Biodiversity Vision will be used for mitigation and adaptation strategies applicable for wetlands, urban ecosystems, and the Lake Erie watershed in Cuyahoga County. These strategies aim to protect biodiversity and the services that ecosystems provide in order to maintain human health. More information can be found on LEAP's website: https://www.leapbio.org/biodiversity-plan.

1. Watersheds - Rivers, Streams and Lake Erie.

The topography and watersheds of Cuyahoga County and Lake Erie has been formed by a sequence of glaciers that carved their way across the terrain (Hales et al., 2008). The most recent glacier, the Laurentian, 12,000 to 14,000 years ago (Hough, 1985) divided the Great Lakes Basin from the Mississippi System and scoured the land to form our current system of streams, rivers, lakes and wetlands throughout northern Ohio. Lake Erie forms the largest and most significant water feature in Cuyahoga County. There are three main rivers within the County that drain into the lake - the Chagrin River (to the east), the Cuyahoga River, (central) and the Rocky River (to the west). Between these river watershed systems and tributaries are numerous small bodies of water with seemingly no connection to any of the rivers or streams. However, all connect through subterranean ground water aquifers recharged by rain and snow-melt.

Lake Erie supplies most of Cuyahoga County's population with water. It also provides ecosystem services for human health, economy, and recreation. Lake Erie's ecosystem functions include sediment transport, floodwater mitigation, water purification and providing habitat for fish, microorganisms, and macroinvertebrates. Services provided also include recreational and commercial fishing, which also generates jobs and revenue. Although ecological services are readily available, it is all contingent on water quality. The water quality can worsen at any time due to algal blooms, industrial chemicals, and heavy metal pollutants. The reduction of water quality threatens the living organisms within the water network, reduces recreational activities, and endangers human health. Additional information on local watersheds and their importance is available at http://www.countyplanning.us/projects/cuyahoga-county-greenprint/watersheds.

The Cuyahoga County Board of Health (CCBH) supports the Northeast Ohio Regional Sewer District (NEORSD) in the management of storm water throughout the County. CCBH maintains ongoing programs for the monitoring of storm water outfalls, the performance of individual residential and semi-public sewage treatment systems, and water quality at Lake Erie beaches. Information on these programs can be found at: http://www.ccbh.net/.

2. Vegetation – Plant Biodiversity

A significant concern in urban environments throughout the County is the reduced indigenous plant biodiversity. Biodiversity is reduced by the removal of native vegetation and trees in particular. Too often, new plantings are non-native ornamentals or invasive species that outcompete native varieties. Protecting the existing vegetation and tree canopy will help ensure diverse, indigenous biodiversity, ecological services, and a heightened environmental resilience. Planting lawns composed mostly of exotic grasses significantly reduces indigenous plant and animal biodiversity (Gillman, 2014).

Using indigenous plants will also help local and endangered pollinators. Pollinator Partnership, a non-profit organization dedicated to the protection and promotion of pollinators and their ecosystems, provides localized planting guides that help communities, neighborhoods and individual property owners create and maintain pollinator friendly habitats. Additional information is available at Planting Guides | Pollinator.org.

3. Human Health and Urban Ecology

Urban ecology is a relatively new branch of traditional ecology and includes anthropogenic (human-made) biomes, also known as anthromes (Ellis and Ramankutty, 2008). It uses the same methods as traditional ecology, but concentrates on regions with high-density, commercial, and residential buildings with paved roads, parking lots and other impermeable surfaces. Urban ecology also focuses on limited vegetation, reduced biodiversity, and a highly modified watershed system. All these features combine to create a unique landscape - the built-environment. This landscape is highly modified from the countryside and natural surroundings and is very dissimilar to previous natural ecosystems formerly studied by ecologists (Niemela, 1999). The dense concentrations of humans in cities create unique habitats and associated, complex human health conditions. Urban ecology and the impacts of climate change on human health assume a greater importance now, as more than 50% of the world's population currently live in cities (Singh, 2014).

In Ohio, Cuyahoga County has the most extensive, urbanized, built-environment, with the greatest amount of impermeable surfaces and the second

highest population in the State. Consequently, Cuyahoga County is likely to suffer some of the greatest effects of climate impacts on human and ecosystem health in the entire state.

The Cuyahoga Greenways Partners (CGP) is an ongoing collaborative whose members include the City of Cleveland and Cuyahoga County Planning Commissions, the Cleveland Metroparks, the Northeast Ohio Areawide Coordinating Agency (NOACA), and others. CGP actively works to advance the implementation of trail and bikeway projects that were identified in the Greenways Plan, a countywide trail and greenway planning initiative completed in 2019. Ultimately, this promotes human health by providing better connectivity of trails and roadways for walkers, cyclists, and joggers.

Cuyahoga Greenways Partners also proposes interlinking fragmented rivers, wooded and other 'green' areas of Cuyahoga County and adjacent counties. The greenway system will also provide corridors for wildlife, both plants and animals, to move more freely. This helps biodiversity preservation, ecosystem connectivity, and improves ecosystem services. Additional information is available at Cuyahoga Greenway Partners – Cuyahoga County Planning Commission.

4. Urban Trees

Before the arrival of settlers in the mid-18th century, the majority of Ohio and adjacent states of; New York, Pennsylvania, West Virginia and Indiana, were covered by trees. Most of the Midwest was predominately forest biome with smaller, embedded biomes such as savanna, grassland, and azonal wetlands (LEAP Biodiversity Vision). Within this forested ecosystem, trees provide the single most important collection of ecosystem functions and benefits for the economy, agriculture, recreation, human health, and overall well-being.

Some of the benefits associated with increased forests in urban areas include the reduction of heat-island effect, decreased storm water runoff, increased biodiversity, and lower temperatures. The current urban selection of tree species and landscaping techniques need to be radically changed to be made ecologically sound (Gillman, 2014). Species indigenous to Cuyahoga County and adjacent counties show the greatest resilience to predicted climate changes (Iverson et al., 2018 a, b) and should

be planted throughout the region.

An urban designer, Dan Burden, has detailed a wide variety of benefits that trees provide in the urban setting ('Urban Street Trees – 22 Benefits'). The Arbor Day's 'Alliance for Community Trees' is a network of community-based organizations dedicated to improving the livability of towns and cities through the planting and caring for trees. Additional information is available at Alliance for Community Trees at arborday.org.

The Cuyahoga County Climate Change Action Plan (CCCCAP), published in 2019, proposed planting as many trees as possible to mitigate climate impacts. The average tree canopy for all 59 communities in Cuyahoga County was 37.6%, which varies from the lowest canopy cover of 9% in the City of Cleveland, to 70% coverage for the Village of Chagrin Falls. Unfortunately, the 2019 tree canopy survey identified a 6% decrease in tree cover for Cuyahoga County. As recommended in the CCCCAP, an Urban Tree Canopy Grant Committee was formed to help promote the process of planting trees locally. In 2019, a $950,000 fund was established to inventory and plant trees with a goal of having 45% of the county's land surface covered by trees by the year 2040 (Healthy Urban Tree Canopy Grant Program – Cuyahoga County Planning Commission).

The Cuyahoga County Greenprint is a set of mapping and planning tools that helps communities see their current resources, learn about current best practices and plan future development. The Greenprint Guide Book provides a series of mitigation and adaptation strategies for enhancing land cover and the local tree canopy. Recommendations for communities and land owners include:

- Protect the existing tree canopy, especially in stream headwaters areas.
- Adopt a tree plan that includes tree planting, maintenance, and tree removal standards, guidelines and policies.
- Adopt a tree replacement policy to ensure that whenever a tree is removed, it will be replaced.
- Consider a tree removal permit system.
- Consider a recompense policy for historically significant or other identified specimen trees in case of harm.
- Adopt development guidelines that require and define tree placement for new construction activities.

73

- Fund a municipal tree maintenance budget.
- Retrofit parking lots with trees or make tree islands and street trees a part of city code or design guidelines.
- Encourage, and consider incentives, for private property owners to plant and maintain more trees, especially in privately held plant-able areas.
- Develop citywide plans and practices to minimize the spread of tree diseases and tree killing insects such as the Emerald Ash Borer and Asian Longhorn Beetle and replace affected trees with a diverse palette of resistant species.
- Adopt landscaping design standards regarding trees for commercial and industrial properties.
- Ensure that landscape design and planting requirements are environmentally and species appropriate to optimize the health and long-term survival of new plantings.
- Identify areas which could expand or connect forest patches and determine the practicality of planting more trees in these areas.
- Develop programs that educate residents on tree stewardship and provide incentives for tree planting and maintenance of forest patches on private property.

The Cleveland Tree Coalition is a partnership focused on creating a healthy and sustainable urban forest so that Cleveland can once again, be known as the 'Forest City'. This collaboration identified trees as a critical piece of the community and developed the Cleveland Tree Plan. The plan looks to make residents healthier and safer, add economic value to homes and businesses, help meet environmental challenges, and provide critical wildlife habitat.

1 tree can absorb 1 ton of carbon dioxide by the time it is 40 years old.
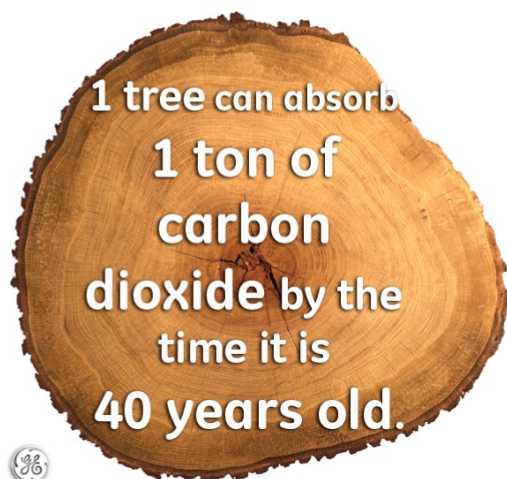
5. Lawns

Lawns represent many things to many people - playing baseball, mowing, weeding, putting or driving a golf ball, playing with kids or pets, etc. In some cases, property owners are only happy when they can look proudly at their beautiful manicured, weed-free, uniform green yard. However, many of these suburban lawns can be considered biological deserts (Dybas, C. 2018) and have outlived their purpose (Garber, M. 2015). Some even consider lawns an ecological disaster (Graber-Stiehl, I. 2018).

It can be expensive to maintain a monocultured lawn, which needs constant mowing, application of fertilizers, pesticides, herbicides and watering.

Photo Credit: Big Stock
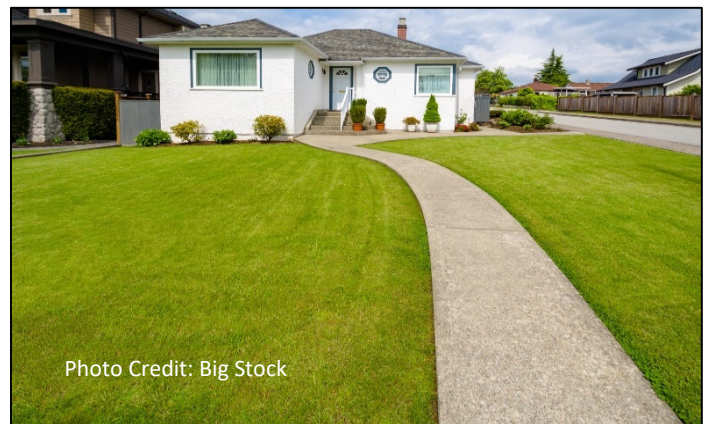
A lawn-desert is created by spraying grass with chemicals. This kills native plants, animals, and microorganisms and sterilizes soils.

PESTICIDE APPLICATION KEEP OFF

Photo Credit: Big Stock

Pictured above are examples of lawn-deserts, spraying grass to kill biodiversity and sterilize soils.

Cuyahoga County is in a region that is considered a forest biome (Stevenson et al., 2018). Unfortunately, new developments continue to clear-cut trees, and

when new buildings are constructed, lawns are planted to replace the former, natural forests. These lawns typically consist of non-native grass monocultures, which reduce indigenous biodiversity. Lawns, at best, are only semi-permeable and do not retain the same volume of rainwater as a healthy forest or even a single native tree. Additionally, soil structure, texture and function are reduced, becoming less permeable and unable to hold storm water runoff, thus increasing flooding potential.

Pesticides and herbicides are regularly applied to lawns, which kill terrestrial and aquatic animals and indigenous pollinator insects. They decrease soil fertility, as well as reducing native plant and animal biodiversity. Fertilizers are often over-applied, which then run off and add nutrients to streams and rivers. Eventually, this process leads to an increase in the potential for algal blooms in Lake Erie. Lawns also require frequent mowing, which adds CO_2 to the atmosphere and increases the potential for pollutant discharges, including petroleum and oil products.

Here are some suggestions to help create more natural lawns:

- Plant native trees and shrubs in clusters throughout the existing lawn
- Stop or reduce the use of fertilizers, pesticides, herbicides and other chemicals used to make lawns look green
- Allow native species of grass, forbs, moss and lichen to re-populate the existing lawn
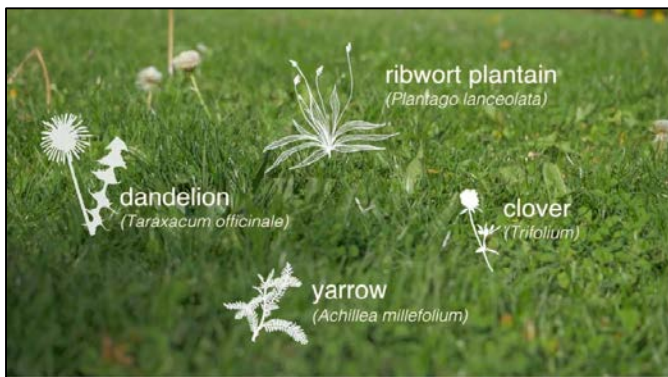- Sow existing lawns with indigenous seed mixes

Image from the Royal Botanic Garden Edinburgh (RBGE), Growing Biodiversity in living lawns.

Indigenous areas covered by grasses include a large percentage of non-graminoid plants, including sedges and rushes. Indigenous "living" lawns typically also include mosses, lichens, bulb plants (geophytes), clovers and dandelion species. A biodiverse, healthy lawn should be composed of numerous species of vascular and non-vascular plants. This will have the added benefit of improving backyard biodiversity for pollinators and other insect species (American Forests, 2019; Robbins, 2007).

In general, the benefits of a biodiverse lawn include more birds visiting the area, improved soil health, reduced storm water runoff, and visually improved (more colorful) lawn aesthetic. Additionally, a biodiverse lawn will cost zero dollars to maintain. It needs no mowing, no fertilizer, and no required application of pesticides or herbicides (Gerber, 2015). A biodiverse lawn will help minimize the potential contamination of streams, rivers, and lakes and will help improve local water quality.

A complex, healthy, biodiverse lawn composed of numerous species of grasses and forbs.

Definitions:

- **Geophyte:** any plant with a below ground storage organ such as a bulb, corm, rhizome, or tuber.
- **Graminoid:** Any grass or grass-like plant. These include sedges (Cyperaceae), rushes (Juncaceae), cat-tails (Typhaceae) or grasses (Poaceae).
- **Forb:** Any herbaceous flowering plant that is not a geophyte or graminoid.

6. Environmental Management and Ecological Restoration

Cuyahoga County, including the City of Cleveland, is highly urbanized, with limited sections of contiguous forests. Any continuous woodland areas are mostly found along the floodplains of the streams and rivers within the jurisdiction of the Cleveland Metroparks.

As a result of minimal connectivity, most ecosystems suffer impairment and loss of biodiversity. Forested patches are subject to human intervention and further

degradation though clear-cutting and bulldozing for development, flooding, erosion, and contamination by pathogenic organisms.

Lake Erie is the second most polluted of the five Great Lakes, with plastics and agricultural nutrients as the main contributors. The pollution within the lake illustrates the inescapable link between human consumption and development, and the health of all ecosystems.

The Northeast Ohio Regional Sewer District (NEORSD), Cleveland Metroparks and various watershed groups are engaged in ongoing ecological restoration projects. Each project aims to reduce the amount of impermeable surfaces, and thus flooding from storm water runoff. These ecological projects include planting trees, restoring former floodplains with wetland vegetation, constructing bio-swales, building and utilizing rainwater barrels, and the extension of downpipes into rainwater gardens.

Photo Credit: BigStock

A vegetated Bioswale which reduces storm water runoff, erosion and provides pollinators with habitat.

A great deal of extensive knowledge has already been utilized to implement existing programs focused on reducing storm water runoff, especially during heavy storms. A primary example is the [NEORSD's combined sewer overflow control program.](#)

Cleveland's earliest sewers are "combined sewers" that carry sanitary sewage and storm water from rain and melting snow in a single pipe. When heavy storms produce large volumes of surface runoff, these combined sewers may not be able to handle the increased volume of water. To prevent sewage from backing up into homes and businesses in these areas, relief points were designed in the system to release the combined flow to the environment. These points are considered combined sewer overflows. In the 1970s, more than 9 billion gallons of combined sewage reached Lake Erie every year. By 2000, that volume was cut in half through a combination of new construction and treatment plant improvements.

The NEORSD launched *Project Clean Lake* in 2010, a 25-year plan for huge storage tunnels, smart green infrastructure, and treatment plant improvements to manage higher flow volumes and reduce overflows. These projects will offer relief for overloaded pipes and keep more storm water out of the combined sewer system, which can also help local communities alleviate sewer backups and flooding problems.

References:
- Barnhill, D.L., and Gottlieb R.S., (eds.), 2010 Deep Ecology and World Religions: New Essays on Sacred Ground, SUNY Press.
- Cleveland Tree Coalition, April 2018. Reforesting the Forest City: The Cleveland Tree Canopy Goal, Cleveland, Ohio.
  Note: The City of Cleveland has a draft tree ordinance (PDF in Appendix; Trees), which will be used as a model for the Cuyahoga County Tree Plan
- Ellis E.C., and Ramankutty N., 2008. Putting people in the map: anthropogenic biomes of the world. Front Ecol Environ 6(8): 439-447, doi: 10.1890/070062
- Gillman D., 2014. Innovation in Ecological Landscape and Planting Design: A process for abstracting native plant communities for use in landscape and planting design, Urban Choreography, ILASA Conference Paper
- Gribbin, J., 1990. Hothouse earth: The greenhouse effect and Gaila, Weidenfeld & Nicolson
- Hales, B., Wei-Jun Cai, Mitchell, B.G., Sabine, C.L., and Schofield, O., (eds.), 2008. North American Continental Margins: A Synthesis and Planning Workshop. Report of the North American Continental Margins Working Group for the U.S. Carbon Cycle Scientific Steering Group and Interagency Working Group. U.S. Carbon Cycle Science Program, Washington, DC, 110 pp.
- Hough J.L., June 1st 1958. Geology and the Great Lakes, University of Illinois Press, 1st edition
- Iverson, L., Peters M., Matthews S., and Prasad A., 19 Sept. 2018, a. An approach to aid in sustainable management of LEAP forestlands into the changing future. US Forest Service, Delaware, Ohio

- Iverson, L., Peters M., Matthew S., and Prasad A., 13 Feb. 2018, b. Evaluating potential tree species changes in suitable habitat in a changing climate, LEAP presentation
- Lovelock, J.E., 1972 Gaia as seen through the atmosphere. Atmospheric Environment. 6 (8) pp. 579-580. Bibcode: 1972 AtmEn...6..579L doi: 10.1016/0004-6981(72)90076-5
- Lovelock, J.E., 1995. The Ages of Gaia: A Biography of Our Living Earth, W.W., Norton & Co.
- Lovelock, J.E., and Margulis, L., 1974. Atmospheric homeostasis by and for the biosphere: the Gaia hypotheses. Tellus. Series A. Stockholm: International Metrological Institute. 26 (1-2): 2-10 Bibcode: 1974, Tell...26...2L doi:10.1111/j.2153-3490.1974.tb01946.x
- ISSN 1600-0870. Retrieved 20 October 2012
- Northeast Ohio Regional Sewer District, Code of Regulations, Title V– Stormwater Management Code, The Sewer District, August 4th 2016
- Niemela, J., 1999. Ecology and urban planning. Biodiversity and Conservation, 8, pp., 119-131
- Raffaelli, D.G., and Frid C.L.J., (eds.), 2010. Ecosystem Ecology: A New Synthesis-bridging the gap between natural and social science to reach holistic management goals, Cambridge University Press, Cambridge, UK, 162 pp. DOI: 10.1017/CBO9780511750458
- Schwartzman, D., 2002. Life, Temperature, and the Earth: The Self-Organizing Biosphere. Columbia University Press. ISBN 0-231-10213-5
- Singh, G., 2014. http://urbanecology.in/2014/10/05/urban-ecology-inputs-need-of-the-urban-era/
- Dybas, C., 2018. Are our lawns biological deserts? National Science Foundation.
- Garber M., 2015. The Life and Death of the American Lawn. Grasses-green, neatly trimmed, symbols of civic virtue-shaped the national landscape. They have now outlived their purpose. The Atlantic, Culture, Aug 28, 2015
- HealthGreenSavvy, 2019. Grass Alternatives: Why & How to Replace Lawns, August 11th 2017, updated May 8th 2019. https://www.heathygreensavvy.com/grass-alternatives/
- Graber-Stiehl, I., 2018. Lawns are an Ecological Disaster , Gizmodo, May 18, 2018.
- Robbins P., 2007. Lawn People. How Grasses, Weeds, and Chemicals Make Us Who We Are. Temple University Press, 9781592135783, 208pp.
- Tallamy, D., 2019. A Call for Backyard Biodiversity, American Forests https://www.americanforests.org/magazine/article/backard-biodiversity/

Useful links to other tree resources and websites:

- Cuyahoga County Planning Commission - http://www.countyplanning.us/projects/cuyahoga-county-greenprint/landcover&treecanopy/
- ITree, which provides information and data to help with tree planting, species, management and costs: https://www.itreetools.org
- The US Forestry Services tree atlas: Tree Atlas - Climate Change Atlas - Northern Research Station, USDA Forest Service (fs.fed.us)
- Vibrant Cities Lab: Urban Forestry Toolkit Toolkit : Vibrant Cities Lab : Resources for Urban Forestry, Trees, and Green Infrastructure
- Center for Watershed Protection Making Urban Trees Count - Center for Watershed Protection (cwp.org)

Other Resources:
- Cleveland Metroparks; list of native plants
- Green Yards and Healthy Homes; the Doan Brook Watershed Partners recently compiled a booklet
- Cleveland Museum of Natural History's list of native plants
- Landscaping Solutions from the Chagrin River Watershed Partners
- Sustainable Pest Management from the Xerces Society