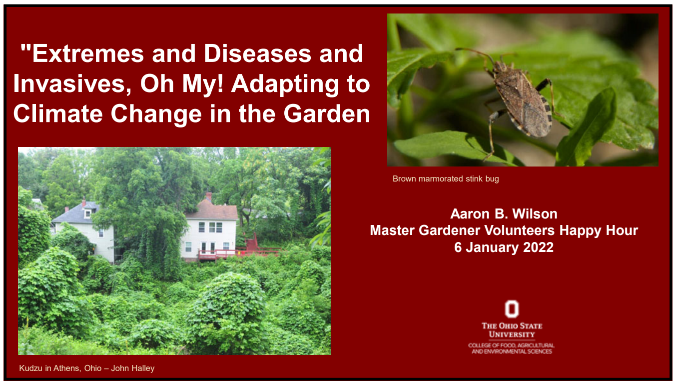
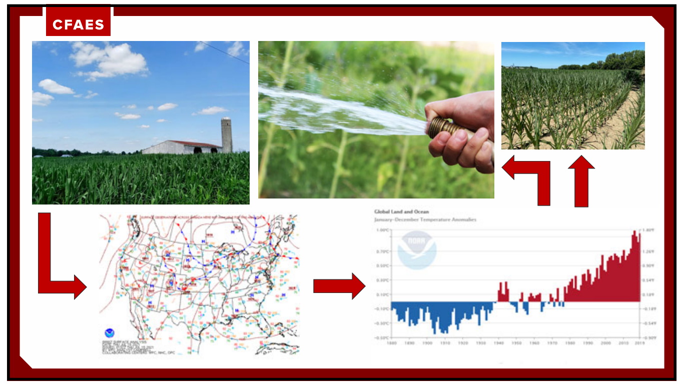
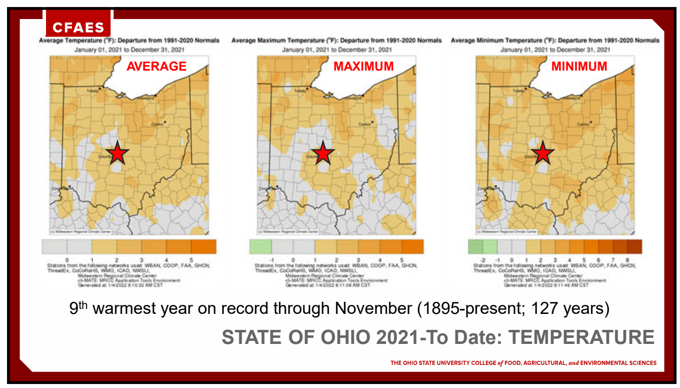
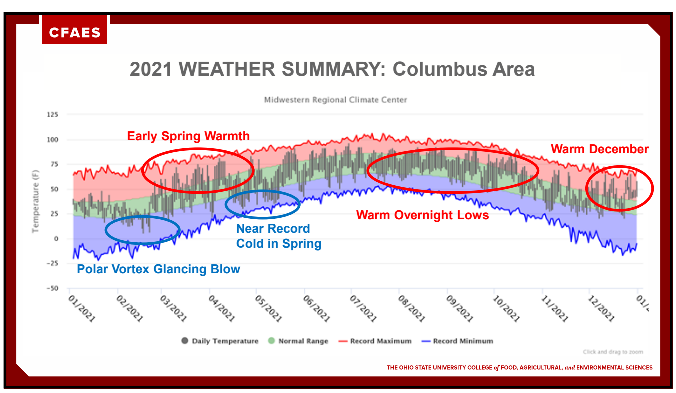
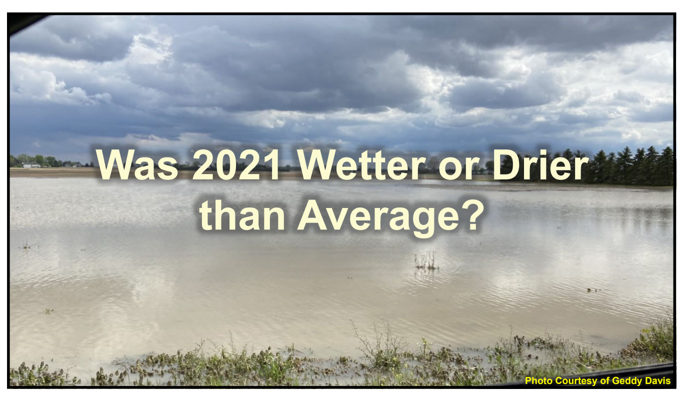

"Extremes and Diseases and Invasives, Oh My! Adapting to Climate Change in the Garden
Brown marmorated stink bug
Aaron B. Wilson
Master Gardener Volunteers Happy Hour
6 January 2022
The Ohio State University
Kudzu in Athens, Ohio – John Halley

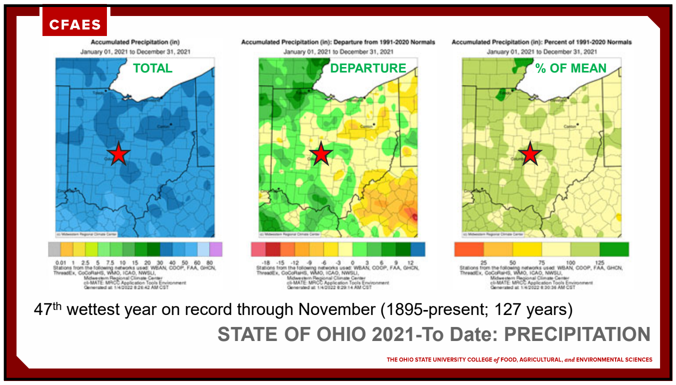

CFAES

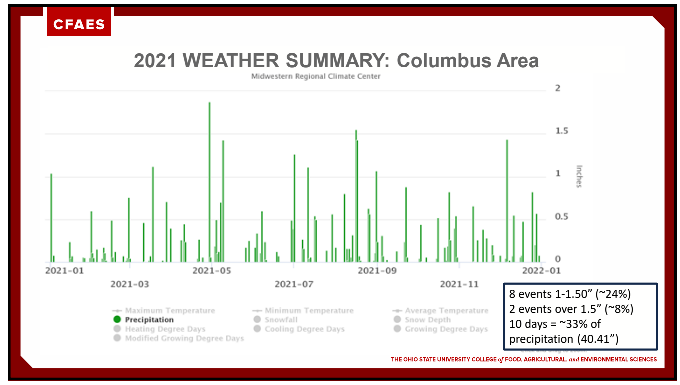

Was 2021 Warmer or Cooler than Average?

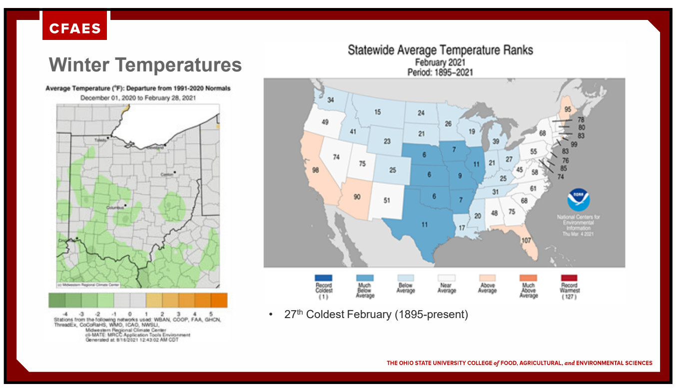

CFAES
AVERAGE
MAXIMUM
MINIMUM
9th warmest year on record through November (1895-present; 127 years)
STATE OF OHIO 2021-To Date: TEMPERATURE
THE OHIO STATE UNIVERSITY COLLEGE of FOOD, AGRICULTURAL, and ENVIRONMENTAL SCIENCES


CFAES
2021 WEATHER SUMMARY: Columbus Area
Midwestern Regional Climate Center
Early Spring Warmth
Warm December
Warm Overnight Lows
Near Record Cold in Spring
Polar Vortex Glancing Blow
Temperature (F)
Daily Temperature
Normal Range
Record Maximum
Record Minimum
THE OHIO STATE UNIVERSITY COLLEGE of FOOD, AGRICULTURAL, and ENVIRONMENTAL SCIENCES


Was 2021 Wetter or Drier than Average?
Photo Courtesy of Geddy Davis


CFAES
Accumulated Precipitation (in)
January 01, 2021 to December 31, 2021
TOTAL
Accumulated Precipitation (in): Departure from 1991-2020 Normals
January 01, 2021 to December 31, 2021
DEPARTURE
Accumulated Precipitation (in): Percent of 1991-2020 Normals
January 01, 2021 to December 31, 2021
% OF MEAN
47th wettest year on record through November (1895-present; 127 years)
STATE OF OHIO 2021-To Date: PRECIPITATION
THE OHIO STATE UNIVERSITY COLLEGE of FOOD, AGRICULTURAL, and ENVIRONMENTAL SCIENCES


CFAES
2021 WEATHER SUMMARY: Columbus Area
Midwestern Regional Climate Center
2021-01
2021-03
2021-05
2021-07
2021-09
2021-11
2022-01
Inches
8 events 1-1.50" (~24%)
2 events over 1.5" (~8%)
10 days = ~33% of precipitation (40.41")
Precipitation
THE OHIO STATE UNIVERSITY COLLEGE of FOOD, AGRICULTURAL, and ENVIRONMENTAL SCIENCES


CFAES
Winter Temperatures
Average Temperature (°F): Departure from 1991-2020 Normals
December 01, 2020 to February 28, 2021
Statewide Average Temperature Ranks
February 2021
Period: 1895–2021
27th Coldest February (1895-present)
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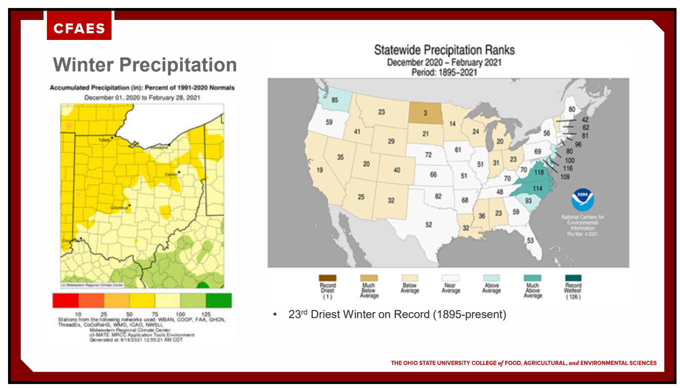
CFAES
Winter Precipitation
Accumulated Precipitation (in): Percent of 1991-2020 Normals
December 01, 2020 to February 28, 2021
Statewide Precipitation Ranks
December 2020 – February 2021
Period: 1895–2021
23rd Driest Winter on Record (1895-present)
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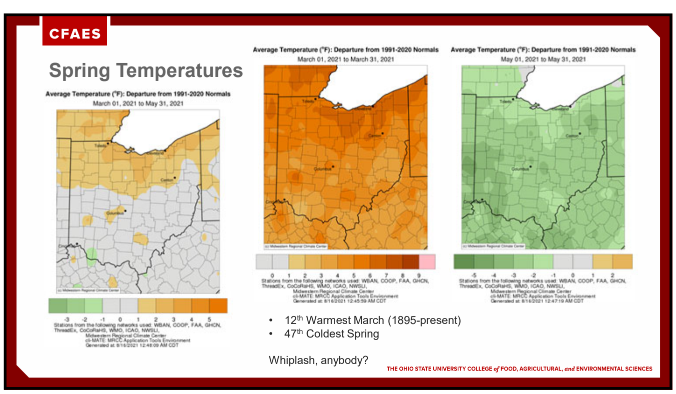
CFAES
Spring Temperatures
Average Temperature (°F): Departure from 1991-2020 Normals
March 01, 2021 to May 31, 2021
Average Temperature (°F): Departure from 1991-2020 Normals
March 01, 2021 to March 31, 2021
Average Temperature (°F): Departure from 1991-2020 Normals
May 01, 2021 to May 31, 2021
12th Warmest March (1895-present)
47th Coldest Spring
Whiplash, anybody?
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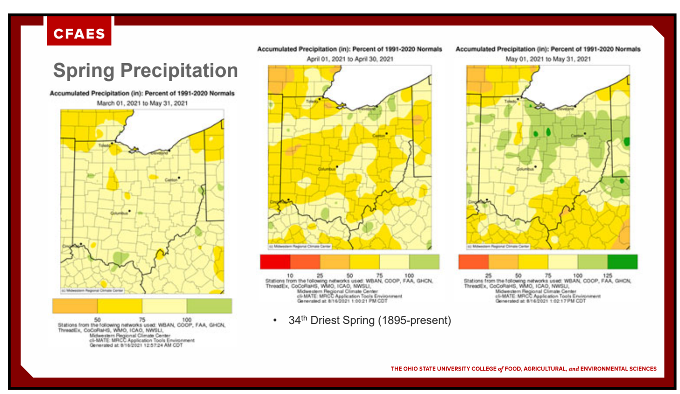
CFAES
Spring Precipitation
Accumulated Precipitation (in): Percent of 1991-2020 Normals
March 01, 2021 to May 31, 2021
Accumulated Precipitation (in): Percent of 1991-2020 Normals
April 01, 2021 to April 30, 2021
Accumulated Precipitation (in): Percent of 1991-2020 Normals
May 01, 2021 to May 31, 2021
34th Driest Spring (1895-present)
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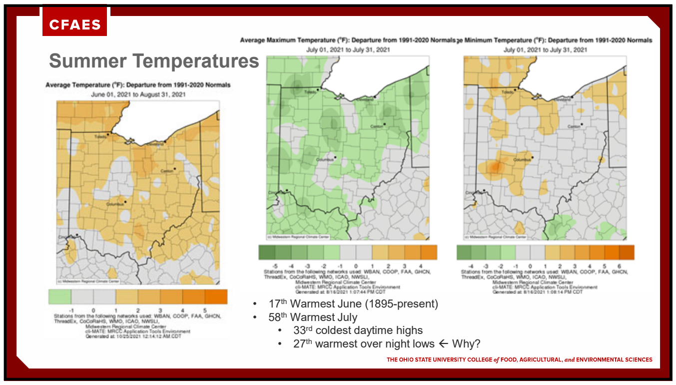
CFAES
Summer Temperatures
Average Temperature (°F): Departure from 1991-2020 Normals
June 01, 2021 to August 31, 2021
Average Maximum Temperature (°F): Departure from 1991-2020 Normals
July 01, 2021 to July 31, 2021
July 01, 2021 to July 31, 2021
• 17th Warmest June (1895-present)
• 58th Warmest July
• 33rd coldest daytime highs
• 27th warmest over night lows ← Why?
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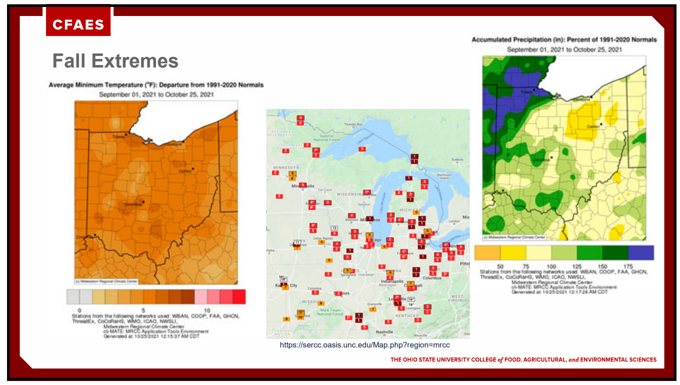
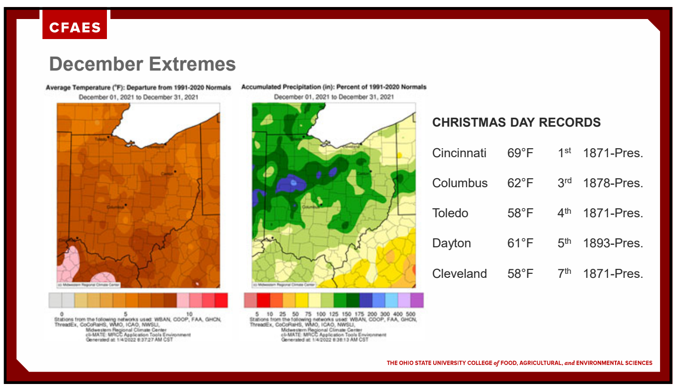

CFAES
Fall Extremes
Average Minimum Temperature (°F): Departure from 1991-2020 Normals
September 01, 2021 to October 25, 2021
Accumulated Precipitation (in): Percent of 1991-2020 Normals
September 01, 2021 to October 25, 2021
https://sercc.oasis.unc.edu/Map.php?region=mrcc
THE OHIO STATE UNIVERSITY COLLEGE of FOOD, AGRICULTURAL, and ENVIRONMENTAL SCIENCES


CFAES
December Extremes
Average Temperature (°F): Departure from 1991-2020 Normals
December 01, 2021 to December 31, 2021
Accumulated Precipitation (in): Percent of 1991-2020 Normals
December 01, 2021 to December 31, 2021
CHRISTMAS DAY RECORDS
Cincinnati 69°F 1st 1871-Pres.
Columbus 62°F 3rd 1878-Pres.
Toledo 58°F 4th 1871-Pres.
Dayton 61°F 5th 1893-Pres.
Cleveland 58°F 7th 1871-Pres.
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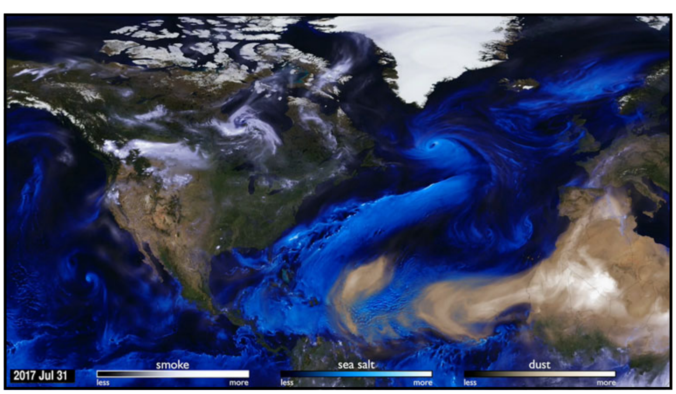
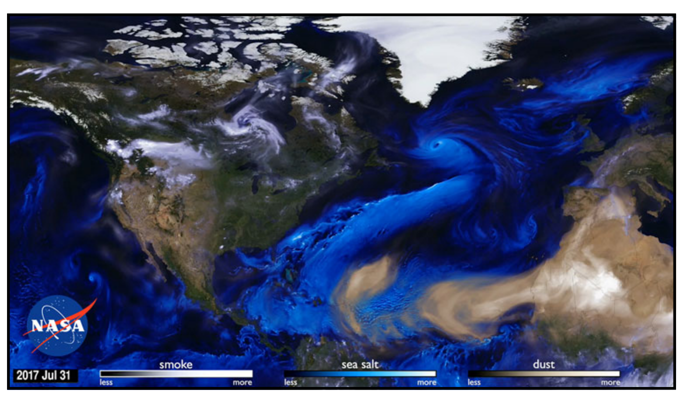
How did the Weather of 2021 Impact You, Your Gardens, or your Local Community?

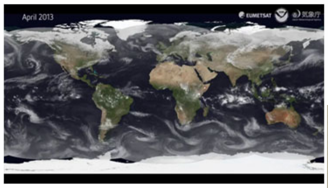

2017 Jul 31
smoke
sea salt
dust
less
more


NASA
2017 Jul 31
smoke
sea salt
dust
less
more

CFAES

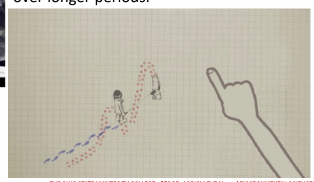
WEATHER AND CLIMATE

Video from UCAR: Center for Science Education - https://scied.ucar.edu/dog-walking-weather-and-climate



Weather: High-frequency changes in temperature, wind speed, etc; Caused by imbalance of energy across the globe.

Climate: Slower-varying aspects; Averages over longer periods.



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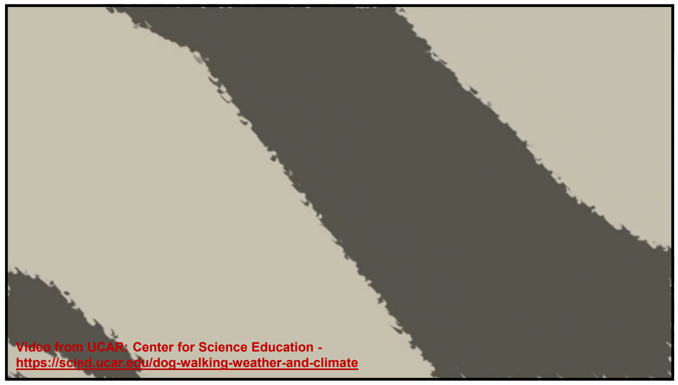
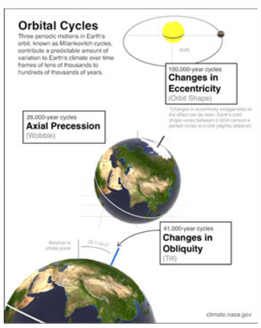


CFAES



EARTH'S ORBITAL CHANGES

- **Eccentricity:** 100K yrs., Varies the amount of radiation the Earth receives during the seasons
- **Precession:** 23K yrs., Earth Wobbles, Closest to sun in January
- **Obliquity:** 41K yrs., Earth is tilted, Less tilt = cooler summers

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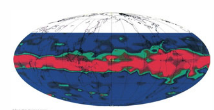
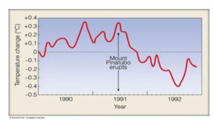
Volcano Impacts are Short-lived

- Only 3 months after the eruption of Mt. Pinatubo, Philippines, the plume girdles the equator in the stratosphere at an altitude near 25 km. (NASA)
- Average global temperature by July 1992, decreased by almost 0.5°C (0.9°F) from the 1981 to 1990 average (dashed line).





CFAES

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But the Earth is old!

- Ohio's GEOLOGICAL WALK THROUGH TIME at the Ohio State Fairgrounds Natural Resources Park (https://tinyurl.com/yywe3wxz)
- Poorly understood periods
- Ohio was well south of the Equator
- Lot of massive tectonic activity
- By Cambrian, Ohio covered by ocean!

United States Geological Survey - Graham, Joseph, Newman, William, and Stacy, John, 2008, Available online at http://pubs.usgs.gov/gip/2008/58/

CFAES

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Ordivician, Silurian, and Devonian (460-360 mya)

- Ohio is covered by sea but rising – sea is becoming shallower
- South of the equator (Near Australia to Near Equator)
- Warm Tropical Sea (started as clear water that eventually filled in with sand)
- Large fossil deposits (Trilobite, corals, snails)

Ohio's GEOLOGICAL WALK THROUGH TIME at the Ohio State Fairgrounds Natural Resources Park (http://www2.ohiodnr.gov/portals/geosurvey/PDFs/Education/el20.pdf)

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Carboniferous: Mississippian and Pennsylvanian (360-300 Mya)

- Ohio is located near Equator
- Risen above sea level – swamp
- Warm, humid, tropical climate with plenty of vegetation
- Lots of ferns, reeds
- Dead organic material became today's coal
- For ~300 Myrs, we lose geological record in Ohio due to erosion by water and wind
- Climate was dominantly warm with high levels of CO_2

Ohio's GEOLOGICAL WALK THROUGH TIME at the Ohio State Fairgrounds Natural Resources Park (http://www2.ohiodnr.gov/portals/geosurvey/PDFs/Education/el20.pdf)

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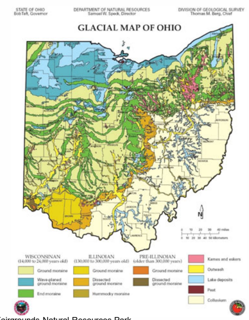
Quaternary: Ice Age Comes to Ohio (~1.6Myr)

- Ohio is located close to current latitude
- Seas have well retreated
- Due to Earth's orbital cycles- ice accumulated in Canada
- Surges and retreats of glaciers make their mark on Ohio's land (~12x)
- During this time, our climate is seeing about 5°C temperature shifts
- Large animals disappear ~ 10,000 ya



Ohio's GEOLOGICAL WALK THROUGH TIME at the Ohio State Fairgrounds Natural Resources Park (http://www2.ohiodnr.gov/portals/geosurvey/PDFs/Education/el20.pdf)

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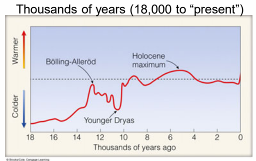
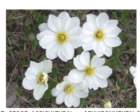
More "Recent" Climate Change

- ~14K ya ice retreated and surface warmed
- Younger Dryas: Abrupt cool period between 13,000-10,000
  - Due to freshwater expulsion into N. Atlantic
- Holocene Maximum – NH continental ice sheets disappeared
  - Remember Earth's Orbital Parameters? Delayed due to ice-albedo feedback.

Thousands of years (18,000 to "present")





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History of CO_2

Joseph Fourier: French, 1768-1830, Greenhouse Effect

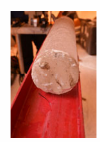
Eunice Newton Foote: American, 1819 – 1888; warming effects of sunlight on different gases

John Tyndall: English, 1820-1893, greenhouse gases

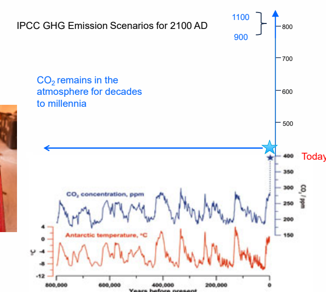
Svante Arrhenius: Swedish, 1859-1927, calculated warming of 2x carbon dioxide concentration

Guy Callendar: English, 1898-1964, temperature anomaly linked to combustion

Charles Keeling: American, 1928-2005, measured carbon dioxide concentrations



IPCC GHG Emission Scenarios for 2100 AD



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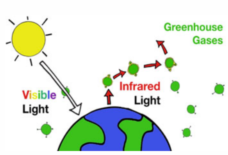
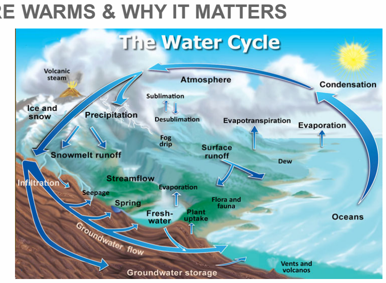
HOW THE ATMOSPHERE WARMS & WHY IT MATTERS



CO_2 and evaporated water become warmer as they absorb infrared radiation from earth's surface trying to escape to space.

HowGlobalWarmingWorks.org, 2014



John Evans and Howard Periman, USGS - http://ga.water.usgs.gov/edu/watercycle.html

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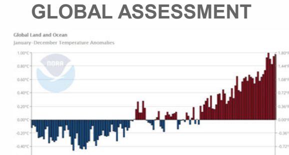
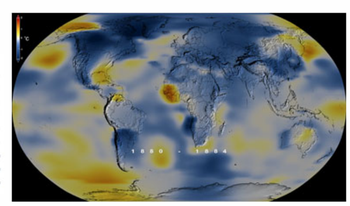
GLOBAL ASSESSMENT





- 2020 is now 2nd warmest year since 1880 (only behind 2016 by 0.04°F)
- Top 10 warmest years have occurred since 2005
- If you were born after February 1985, you have never experienced a cooler than average month for the planet!
- 2021 currently 6th warmest

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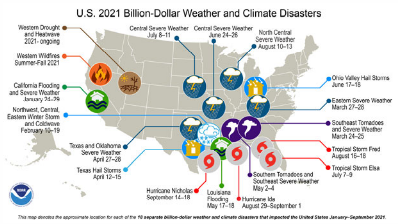
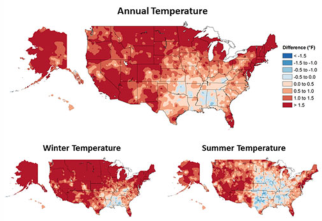
BILLION DOLLAR DISASTERS



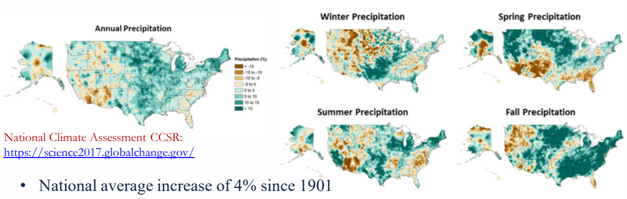
ANNUAL AND SEASONAL DIFFERENCE OF WARMING



- More than 95% of the land surface demonstrated an increase in annual average temperature
- Paleoclimate records suggest recent period the warmest in at least the past 1,500 years
- Greatest and most widespread in winter

Annual average temperature over the contiguous United States has increased by 1.2°F (0.7°C) for the period 1986–2016 relative to 1901–1960 and by 1.8°F (1.0°C) based on a linear regression for the period 1895–2016: National Climate Assessment CCSR: https://science2017.globalchange.gov/

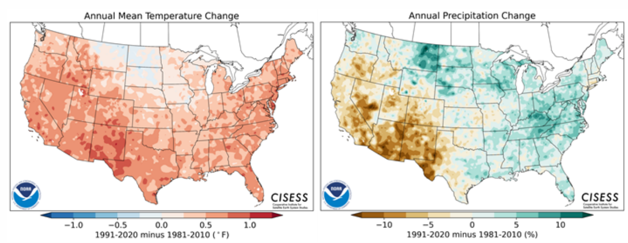
ANNUAL & SEASONAL CHANGES IN PRECIPITATION



National Climate Assessment CCSR: https://science2017.globalchange.gov/

- National average increase of 4% since 1901
- Ohio: 5-15%; Driven strongly by fall trends (10-15% in some locations)
- Regional Spring, Summer, and Fall Trends across Ohio
- Increased Intensity of rainfall events

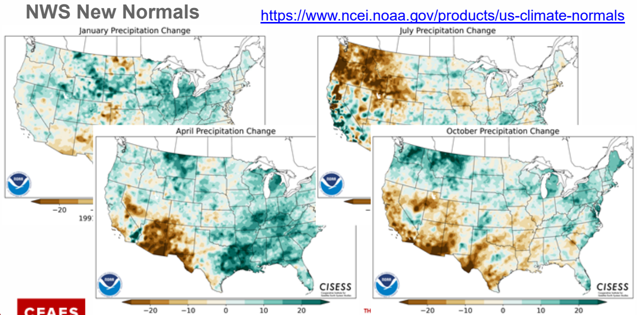
NWS New Normals



https://www.ncei.noaa.gov/products/us-climate-normals

NWS New Normals

https://www.ncei.noaa.gov/products/us-climate-normals



TEMPERATURE			
RANK	YEAR	AVERAGE	DIFFERENCE
1	1998	54.1	2.9
2	2012	54.0	2.8
3	2016	53.6	2.4
4	1921	53.5	2.3
5	2017	53.2	2.0
6	1991	53.1	1.9
7	2020	53.0	1.8
8	1931	52.9	1.7
9	2006	52.7	1.5
9	1990	52.7	1.5

PRECIPITATION			
RANK	YEAR	TOTAL	DIFFERENCE
1	2011	55.95	16.50
2	1990	51.07	11.62
3	2018	50.93	11.38
4	1950	48.34	8.89
5	2019	46.87	7.42
6	1996	46.85	7.40
7	2003	46.42	6.97
8	1929	46.07	6.62
9	2017	45.51	6.06
10	2004	45.45	6.00

- 5 of the top 10 warmest/ 6 of the top 10 wettest have occurred since 2003
- 8 of the top 10 warmest/ 8 of the top 10 wettest since 1990

OHIO'S TOP 10

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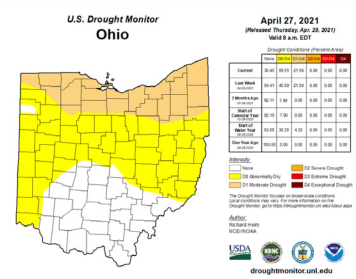
We Still See Drought

- Distinguish meteorological drought (lack of precipitation) from agricultural drought (soil moisture deficit) and hydrological drought (runoff deficit)
- Precipitation trends lead to lower confidence in detectable changes in meteorological drought
- Recent droughts distinguished from past (1930s/50s)
- Droughts drier due to warmer temperatures and increased evaporation



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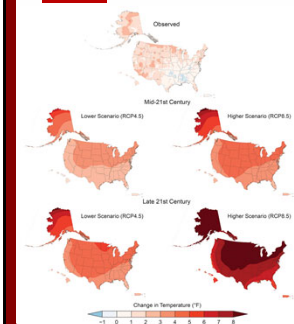
CFAES



OUR FUTURE CLIMATE: TEMPERATURE

- Driven by winter warming and warmer nighttime temperatures
- Mid-Century Change: 3-5°F warmer
- Late-Century Change: 4-8°F warmer

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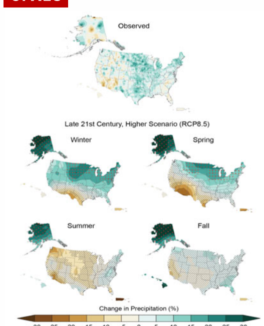

OUR FUTURE CLIMATE: PRECIPITATION

- Driven by increased water vapor (humidity)
- Seasonal changes atmospheric circulation
- Wetter cool season; drier summer season = could mean intensified drought

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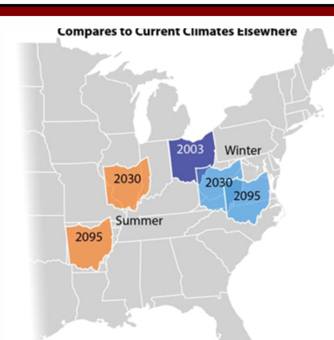
WHAT IF THIS IS OUR NEW NORMAL?

- Longer Growing Season
- Warmer Temperatures (Winter and at Night)
- Higher Humidity
- More Rainfall
- More Intense Rainfall Events
- More Autumn Precipitation



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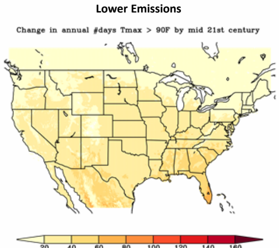
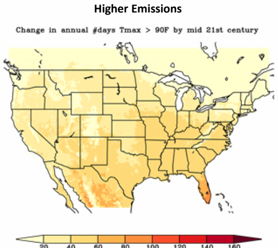
https://scenarios.globalchange.gov/loca-viewer/

CHANGE IN # OF DAYS > 90°F

Lower Emissions



Higher Emissions



(1976-2005): 20-40 days per year

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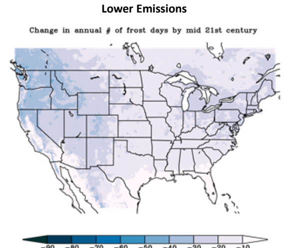
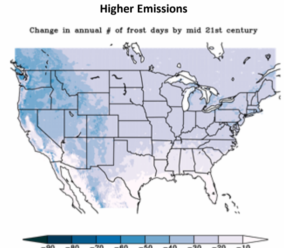
https://scenarios.globalchange.gov/loca-viewer/

CHANGE IN # OF NIGHTS > 32°f

Lower Emissions



Higher Emissions



Ohio (1976-2005): 80-160 days per year

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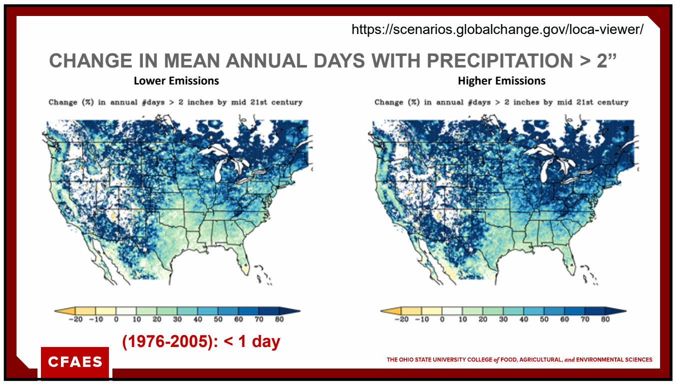
https://scenarios.globalchange.gov/loca-viewer/
CHANGE IN MEAN ANNUAL DAYS WITH PRECIPITATION > 2"
Lower Emissions
Higher Emissions
Change (%) in annual #days > 2 inches by mid 21st century
Change (%) in annual #days > 2 inches by mid 21st century
−20 −10 0 10 20 30 40 50 60 70 80
−20 −10 0 10 20 30 40 50 60 70 80
(1976-2005): < 1 day
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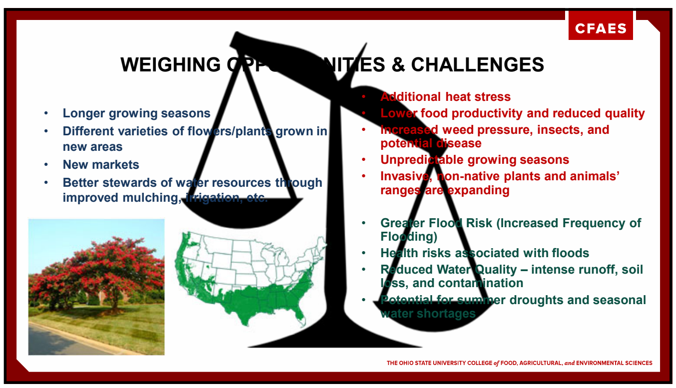
How have (will) YOU or YOUR LOCAL COMMUNITY been impacted our changing climate?
Squash Vine Borer Moth (Melittia cucurbitae) feeding on a Gooseneck Loostrife flower (Lysimachia clethroides). Photo Credit: Distant Hill Gardens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WEIGHING OPPORTUNITIES & CHALLENGES
Longer growing seasons
Different varieties of flowers/plants grown in new areas
New markets
Better stewards of water resources through improved mulching, irrigation, etc.
Additional heat stress
Lower food productivity and reduced quality
Increased weed pressure, insects, and potential disease
Unpredictable growing seasons
Invasive, non-native plants and animals' ranges are expanding
Greater Flood Risk (Increased Frequency of Flooding)
Health risks associated with floods
Reduced Water Quality – intense runoff, soil loss, and contamination
Potential for summer droughts and seasonal water shortages
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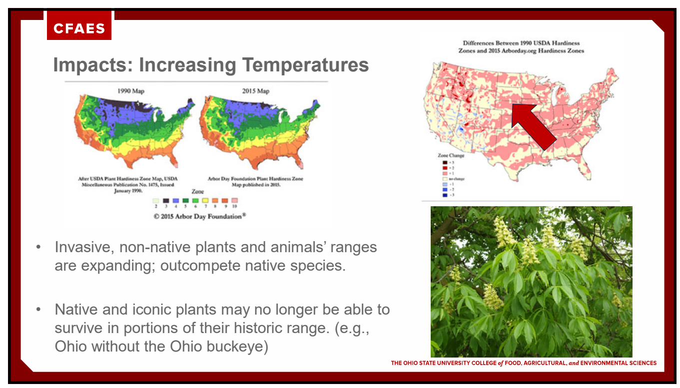
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Impacts: Increasing Temperatures
1990 Map
2015 Map
© 2015 Arbor Day Foundation®
Differences Between 1990 USDA Hardiness Zones and 2015 Arborday.org Hardiness Zones
Invasive, non-native plants and animals' ranges are expanding; outcompete native species.
Native and iconic plants may no longer be able to survive in portions of their historic range. (e.g., Ohio without the Ohio buckeye)
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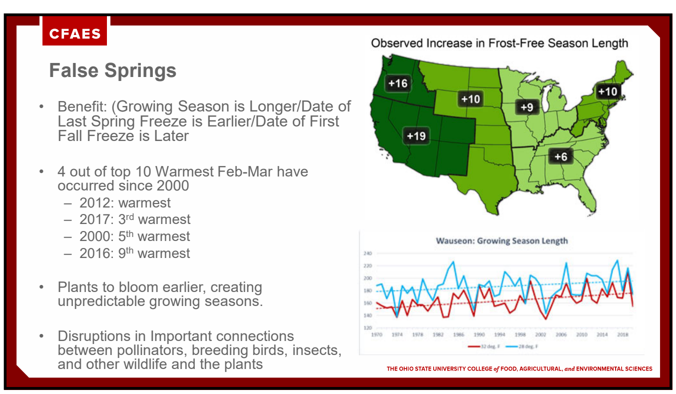
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False Springs
Benefit: (Growing Season is Longer/Date of Last Spring Freeze is Earlier/Date of First Fall Freeze is Later
4 out of top 10 Warmest Feb-Mar have occurred since 2000
– 2012: warmest
– 2017: 3rd warmest
– 2000: 5th warmest
– 2016: 9th warmest
Plants to bloom earlier, creating unpredictable growing seasons.
Disruptions in Important connections between pollinators, breeding birds, insects, and other wildlife and the plants
Observed Increase in Frost-Free Season Length
+16
+10
+9
+10
+19
+6
Wauseon: Growing Season Length
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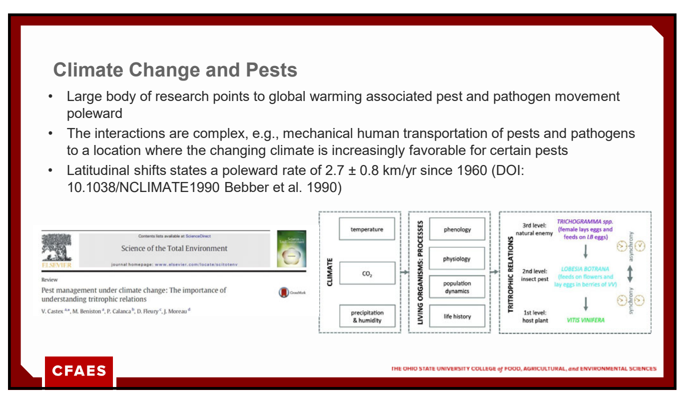
Climate Change and Pests
Large body of research points to global warming associated pest and pathogen movement poleward
The interactions are complex, e.g., mechanical human transportation of pests and pathogens to a location where the changing climate is increasingly favorable for certain pests
Latitudinal shifts states a poleward rate of 2.7 ± 0.8 km/yr since 1960 (DOI: 10.1038/NCLIMATE1990 Bebber et al. 1990)
Science of the Total Environment
Pest management under climate change: The importance of understanding tritrophic relations
CLIMATE
temperature
CO2
precipitation & humidity
LIVING ORGANISMS: PROCESSES
phenology
physiology
population dynamics
life history
TRITROPHIC RELATIONS
3rd level: natural enemy
2nd level: insect pest
1st level: host plant
VITIS VINIFERA
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Japanese Beetles

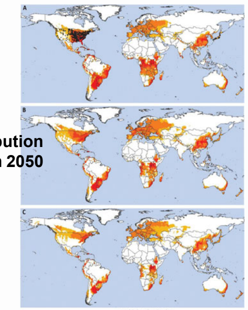
The Potential Global Distribution and Voltinism of the Japanese Beetle (Coleoptera: Scarabaeidae) Under Current and Future Climates

Erica Jean Kistner-Thomas

Journal of Insect Science, Volume 19, Issue 2, March 2019, 16, https://doi.org/10.1093/jisesa/iez023

Published: 22 March 2019 **Article history**

Distribution in 2050



- Temperature, Threshold Annual Heat Sum, Moisture, Cold Stress, Heat Stress, Dry Stress, Wet Stress, Hot–Wet Stress
- North America: projected increases in temperature would enable northward range expansion across Canada
- Europe: the suitable range for P. japonica would increase by 23% by midcentury, especially across portions of the United Kingdom, Ireland, and Scandinavia

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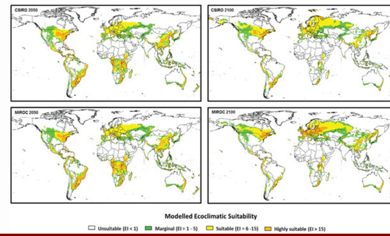
Brown Marmorated Stink Bug

Climate Change Impacts on the Potential Distribution and Abundance of the Brown Marmorated Stink Bug (Hemiptera: Pentatomidae) With Special Reference to North America and Europe

Erica Jean Kistner

- Suitable range in Europe and North America expands northward; contracts from its southern temperature range
- Prolonged periods of warm temperatures resulted in longer H. halys growing seasons.
- Rising summer temperatures decrease H. halys growth potential - may reduce mid-summer crop damage.
- Climate change may increase the number of generations produced
- annually, thereby enabling the invasive insect to become multivoltine in the northern latitudes



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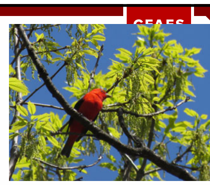
Impacts on Birds

- Survival by Degrees (https://www.audubon.org/climate/survivalbydegrees)
  - Two-thirds of North American birds are at increasing risk of extinction from global temperature rise.
  - Holding warming to 1.5°C above pre-industrial levels, 76 percent of vulnerable species will be better off, and nearly 150 species would no longer be vulnerable to extinction from climate change.

Spring Heat

Loss of Habitat

Loss of Wetlands in the Midwest



Intense Rainfall

Increased Fire Activity

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What can WE or OUR COMMUNITIES DO?

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1. Climate change is happening.
2. We are currently experiencing the effects.
3. Humans are the cause.
4. The scientific evidence is overwhelming.
5. We can do something about it.

Mitigate: Stop or limit climate change impacts by reducing greenhouse gas emissions.

Adapt: Change infrastructure, planning, and behaviors to adjust to climate change impacts.

Suffer: Face the consequences of failing to mitigate or adapt. Populations already experiencing adversity are likely to be the most negatively impacted.

Talk About It!!!

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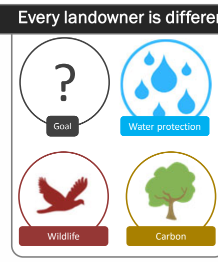
ADAPTATION: There is no single answer

NIACS

Every landowner is different



Each decision is unique and will vary based upon:

People: Values, Culture, & Resources

Place: Location & Site Conditions

Purpose: Goals & Objectives

Practices: Equipment, Procedures, & Methods

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Horticulture and Adaptation

Improve water harvesting and storage

- dams and catchments to cope with projected rainfall and evaporation rates
- use in-row water harvesting for grapes and tree crops
- harvest water run-off from greenhouses
- increase investment in tanks and dam storages.

Improve irrigation efficiency

- watering at night; drip irrigation; subsurface drip irrigation
- reduced evaporation of soil water through mulching with organic materials, mulching with plastic, rapid crop canopy development/closure
- reducing run-off by using appropriate irrigation rates, mulches, contour sowing, minimum tillage, claying.

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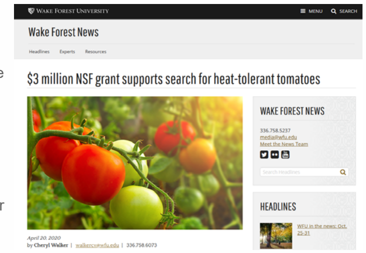
Horticulture and Adaptation

Manage higher temperatures

- crop regulation and canopy management, such as using temperature data loggers to optimize temperatures; greenhouse modifications
- using irrigation to ameliorate temperature extremes; sprinkler irrigation can reduce canopy temperatures.
- Vegetable/Fruit hybrids with greater heat tolerance



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Soil Health at the Heart of Adaptation and Mitigation

- Healthy soils impacted by erosion, compaction, and loss of organic matter.
- Food and Agriculture Organization of the United Nations: "It is estimated that soils can sequester around 20 Pg C in 25 years, more than 10 % of the anthropogenic emissions." – Rattan Lal
- Compost can reduce greenhouse gas emissions at landfills, promote uptake of carbon dioxide by vegetation, and help build resilience to climate change in our gardens.

(https://www.compostingcouncil.org/page/ClimateChangeBenefits)

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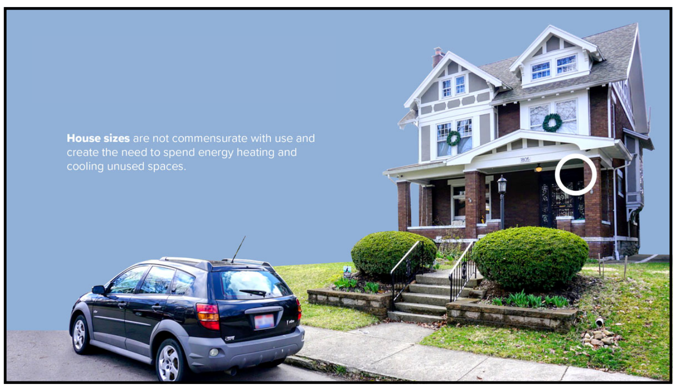
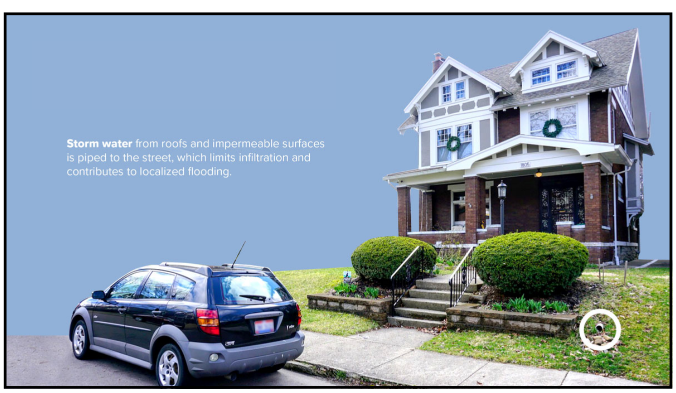
Roofing surfaces absorb incoming solar radiation and contribute to the urban heat island.

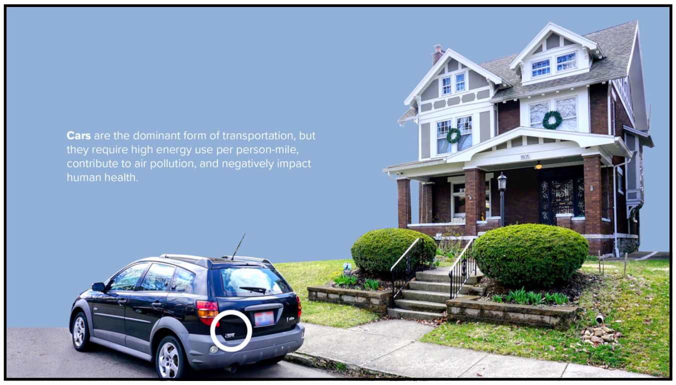

Outdoor lighting emits light without regard for specific demand, uses energy inefficiently, and contributes to light pollution that impacts both people and wildlife.

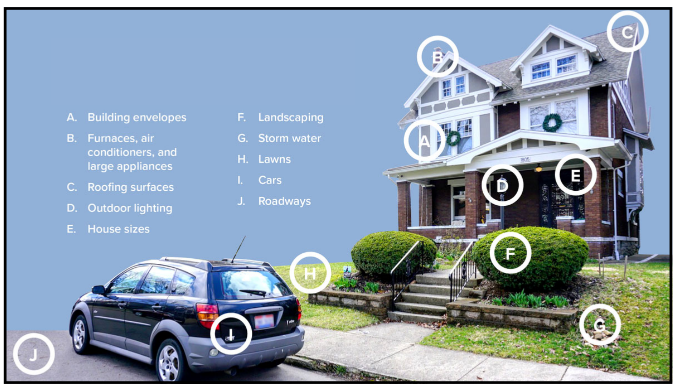

House sizes are not commensurate with use and create the need to spend energy heating and cooling unused spaces.


Landscaping is not native, does not contribute to local biodiversity, and is intolerant of climate without time, resources, and energy.


Storm water from roofs and impermeable surfaces is piped to the street, which limits infiltration and contributes to localized flooding.


Lawns are monocultures that demand time, resources, and energy, but provide little functional value for people or wildlife.





Climate Solutions are in Gardeners' Hands

Take Action in Your Backyard and Community

- Improve your energy efficiency; Reduce the use of gasoline-powered yard tools.
- Reduce the threat of invasive species expansion; natives or drought-tolerant species
- Reduce water consumption; Adjust watering schedules; Improved mulching
- Compost kitchen and garden waste.
- Plant lots of trees to absorb carbon dioxide; Climate Tree Atlas (https://www.fs.fed.us/nrs/atlas/tree/)
- Connect places for wildlife by certifying your backyard or neighborhood as a Certified Wildlife Habitat™ with the National Wildlife Federation.

https://www.nwf.org/Our-Work/Environmental-Threats/Climate-Change/Greenhouse-Gases/Gardening-for-Climate-Change

https://www.invasivespeciesinfo.gov/subject/climate-change

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