State of the Science

May 2023 | Volume 10 | Larry M. Antosch, Ph.D.

The State of the Science Report is published periodically to provide an update on Ohio and national water quality research and emerging issues. The May 2023 edition explores the challenges faced by Ohio agriculture due to changing weather patterns and climate.

Ohio's Agriculture in a Changing Climate

Agriculture has always been at the mercy of Mother Nature. Often, it is either too wet or too dry, too hot or too cold. Even with this day to day, month to month and year to year variation, historically there was a degree of reliability year after year to knowing when it was time to plant and when it was time to harvest.

Throughout history, climate impacts on crop production are notable. Crop yields have been impacted by past weather extremes of droughts and floods. Water availability coupled with elevated temperatures are dominant climatic factors

Key Terms

Climate - Generally prevailing weather conditions (precipitation, temperature, humidity, sunshine, cloudiness and winds) for a particular place and time period, usually averaged over a 30-year time period.

Climate Adaptation - Efforts to prepare for or cope with the impacts of changing climate conditions.

False Spring - Horticultural term referring to a period of weather in late winter or early spring, when temperatures are significantly above normal and extend for a period of time. During a false spring, vegetation is "tricked or fooled" out of dormancy and animals out of hibernation.

Flash Drought - The rapid onset or intensification of drought that occurs when low precipitation is accompanied by abnormally high temperatures, high winds, and/or changes in radiation.

Invasive Species - A species that has been introduced to an area outside of its native habitat, where it can have negative ecological, economic or human health impacts.

Seasonality - Recurring events or processes that are correlated with seasons, such as rising temperatures at the end of winter, the blooming of wildflowers in spring, the onset of allergies during ragweed season, and leaf-fall in autumn.

Thermal Comfort Zone - The range of ambient temperatures in which normal metabolism provides enough heat to maintain an essentially constant body temperature.

Weather - The short-term (minutes to months) changes in the atmosphere. Most people think of weather in terms of temperature, humidity, precipitation, cloudiness, brightness, visibility, wind, and atmospheric pressure, as in high and low pressure creating variations in crop yields. In most years, decreases in crop yields have occurred due to short-term exposure to stresses characterized by lack of adequate soil moisture or temperatures outside of the optimal range for plant growth.

It is not surprising that farmers are recognizing changes in weather patterns. In a recent Ohio State University survey of 918 farmers in the Corn Belt, 51% indicated that they believed that climate was changing. While the respondents indicated they personally have experienced the impacts of changing weather patterns (e.g. warmer winters, variable planting dates, variable rainfall), these impacts were only a slight concern to most respondents.

REGIONAL TRENDS

A number of large-scale regional weather changes have been observed within the Northeast and Midwest United States:

- Warming is occurring in every season, particularly in winter.
- Heatwaves have become more frequent, more intense, and last longer.
- Precipitation amounts are increasing, particularly in fall, winter and spring.
- The number of summer high-intensity precipitation events is increasing.
- Snow is shifting to rain, leading to increased rain-on-snow winter runoff events and increased runoff volumes.
- Atmospheric moisture content (clouds and humidity) is increasing.
- Wind speeds are declining, though wind gusts are intensifying.
- Thunderstorms are becoming more severe.
- Floods are intensifying, yet droughts are also on the rise as dry periods between precipitation events are getting longer (flash droughts).
- Growing seasons are getting longer, with more growing degree days accumulating earlier in the season.

OHIO TRENDS

Ohio's climate is changing. Over the past century, Ohio has gotten warmer and wetter. Floods are becoming more frequent as the number of extreme rainfall events have increased. Elevated temperatures coupled with dry summer growing seasons increases the need for irrigation.

- **Temperature –** Average annual temperatures in Ohio have risen more than 1.5oF since the beginning of the 20th century. The warming has been concentrated in the winter and spring. While summer day-time temperatures have not increased substantially, there has been an increase in the summer night-time temperatures and an increase in the number of warm nights (temperature of 70 degrees or higher).

- **Growing Season –** The length of the growing season (annual frost-free season) in Ohio has increased by 9 days over the past several decades. Most of the change taking place is a result of earlier date for the last spring freeze and a later date for the first fall freeze.

- **Precipitation –** The number of heavy (2-inch or more) rain events in Ohio has significantly increased in since the mid-1990s resulting in an increase in flooding events. Coupled with an increase in winter and spring-time rainfall, the number of wet days and multiple wet day events have increased by as much as 30% across the state.

CHALLENGES FOR OHIO AGRICULTURE

The agricultural sector in Ohio is highly sensitive to shifts in temperature and precipitation which directly affect crop growth as well as livestock and poultry productivity. Shifting climate patterns also have indirect effects on agriculture through altered patterns and prevalence of weeds, pathogens, insects and invasive species. Though doing it subconsciously, Ohio farmers need to develop personalized strategies to adapt to the changing weather.

Temperature

Under a warming climate, spring is arriving earlier and the frost free season has been increased by 9 days. An earlier spring, coupled with a later autumn, means longer growing seasons. For farmers, this means opportunities to double crop or try new crops. Generally, longer growing seasons favor agricultural production. However, warming winters increase the survival and reproduction of insect pests and are enabling a northward range expansion of new pests and crop pathogens.

Crops have a specific temperature range characterized by a lower and upper limit in which growth stops and an optimal temperature at which growth proceeds at a rate for maximum production. Increases in growing-season temperatures are projected to be the largest contributing factor to declines in the productivity of U.S. agriculture. Projections show that surface soil moisture will likely transition from excessive levels during spring, due to increased precipitation, to levels that are insufficient to support growth during summer. Driven by higher temperatures, increased evaporation will reduce moisture levels leading to an increase in short-term "flash droughts". Projections of mid-century yields show declines of up to 25 percent for corn and soybeans.

Earlier springs, especially when coupled with late frosts, can mean trouble for plants and animals. Crops that break too early from winter dormancy may cause plants to lose their tolerance for later cold spells (which they might have otherwise tolerated). Earlier bud break followed by a hard frost may cause plants to lose leaves and flowers, reducing later season productivity and their ability to reproduce. Tree fruits, including apples and peaches are especially vulnerable to these spring freeze events.

The occurrence of these "false springs" has been increasing. Earlier return of migratory birds may not be synchronized with the food sources they expect to find on their arrival and earlier nesting followed by extreme cold may cause birds to lose their first clutch of nestlings. The concept of "seasonality" relates to events that are correlated to the seasons and can be impacted by our changing climate in three ways: the timing when a seasonal event occurs, the length of time a seasonal event lasts and changes in the intensity and frequency of seasonal events.

Some consequences of an earlier spring are easy to see like the earlier onset of flowering.

Others are more difficult. As air temperatures warm above freezing in the early spring, soil temperatures also increase. During an early warm spell, soil temperatures can jump from slightly above freezing (32 o F) to 40 o F or warmer in as little as a day. This below ground "spring trigger" tells the soil microbes and tree roots to "wake up", start increasing their biological activity and prepare for spring. Studies have shown that this 'spring trigger' is occurring more than 14 days earlier than it did 50 years ago.

The average annual air temperature in Ohio has risen more than 1.5 o F since the beginning of the 20th century. The warming has been concentrated in the winter and spring. While summer day-time temperatures have not increased substantially, there has been an increase in the summer night-time temperatures and an increase in the number of warm nights (temperature of 70 o F or higher). Increasing nighttime temperatures have a negative impact on plant growth and yield. Rising low night-time temperatures increase plant respiration which diverts sugars for energy rather than being converted into starch for grain. Additionally, elevated temperatures can alter the timing of when pollen is produced and the flower pistil emerges reducing the number of seeds produced.

Precipitation

Changes in precipitation patterns (timing, amount, intensity and severity of rainfall events) have a large impact on Ohio agriculture. Overall, the total annual precipitation in Ohio has increased by about 10-15% since 1990. This change has not occurred uniformly across all 4 seasons. Wetter conditions are occurring during the winter, spring and fall with drying conditions in the summer.

Increased rainfall from April to June is considered the single trend with the highest impact on Ohio agriculture. Spring precipitation has increased 15-17% (1.5 – 2.0 inches) across Ohio with April having the largest increase (24%). In addition to the 24% increase in total precipitation, the number of rainfall events greater than 0.5 inch and greater than 1.0 inch have also increased. The increase in spring precipitation disrupts field preparation, planting and crop establishment. Even with the increase in the length of the growing season, too much spring rainfall leads to a reduction in the number of days available for field work and can lead to labor issues as field work is delayed.

The way that rainfall is being delivered is also having an impact of Ohio agriculture. The frequency of heavy rainstorms, both 24-hour and multiday, has doubled since the early 1900s. Heavy summer downpours have become more frequent, contributing to increases in soil erosion and flooding in small and medium-sized streams.

Summer rainfall is becoming more intense and shorter in duration with longer dry periods between events. Elevated summer temperatures lead to higher water evaporation from soil and plants requiring additional rainfall to maintain soil moisture levels. Less summer rains lead to short-term droughts (flash droughts) and the increased need for irrigation.

Weeds, Pests, and Disease

Warming temperatures and increased precipitation and humidity will influence weed, pest and disease incidence in several ways. Warmer and shorter winters mean that crop pests and pathogens that are normally kept in check by cold temperatures can expand their ranges northward. Warming will increase the rate of insect development and the number of generations that can be completed each year, contributing to a build-up of pest populations. Leaf and root pathogens are highly responsive to seasonal increases in precipitation and humidity. Rising temperatures can enhance the northern expansion of invasive weeds common in the southern United States.

In a warmer, wetter but longer growing season, weeds, pests and plant diseases will be more prevalent. The use of pesticides is expected to increase. Increasing wind gusts will impact the ability to spray making control a challenge.

Livestock

Climate directly impacts livestock feed intake and growth rates; milk, meat and egg production; decrease in reproductive performance; and increased morbidity and mortality and indirectly by impacting the quality of the feed supply. The combination of air temperature, humidity and air movement affects animal production. When these three factors are in alignment and optimized, animals are in their thermal comfort zone. When conditions are within this zone, animals exhibit optimum performance. When conditions rise above this zone, animals experience heat stress resulting in reduced feed intake and growth rates; decline in milk production; changes in milk composition, decreased meat production and quality; decreased egg shell quality and reduced egg production.

Indirectly, changing weather patterns will impact livestock production through influences on the quality of forages and crop-based feeds, composition of pastures and increased disease and parasite stress. Periods of hot weather can cause livestock to be more vulnerable to diseases and raise the incidence of certain diseases (such as mastitis), leading to an increased potential of morbidity and death.

MIGRATING STATE

What future climate conditions should Ohio farmers be prepared for? A tool often used to illustrate future climate and how changing climate might affect a specific state is to conduct a migrating state analysis. A migrating state analysis is a dramatic way of visualizing projected future climate conditions in a state and comparing them with present day climate conditions in other states today. Projected changes in temperature, humidity and precipitation will alter how climate feels to Ohio residents. Based on projected temperature, humidity and precipitation, future Ohio summers might resemble those in Arkansas and future Ohio winters might become similar to those in Virginia.

FARMERS ADJUST AND ADAPT

Farmers in the Midwest have been increasingly impacted by climate change-related extreme weather events over the last several decades. Droughts, extreme rain events, floods, tornados and derechos have damaged crops, killed livestock, destroyed homes, barns and grain storage structures. As a result, Midwest farmers are developing and implementing adaptive strategies to cope effectively with these impacts. Farmers have always employed different adaptation strategies to prevent yield reductions due to weather variability. Climate change and the more variable and extreme weather it brings has made taking adaptive action more urgent.

Two farmer surveys were conducted across several the midwestern Corn Belt states (Wisconsin, Illinois, Iowa, Indiana, Michigan and Ohio) to investigate the factors associated with farmer adaptation to changes in extreme weather. The surveys revealed that farmers recognize that the climate is changing and they are experiencing climate impacts in their day-to-day farming operation. To combat these impacts, many farmers have taken adaptive actions. Planting more resilient varieties of crops, outsourcing some on-farm activities, changing tillage practices and installing additional drain tile are common adaptation strategies.

Key Takeaway Messages

- Changes in temperature and precipitation patterns has disrupted the timing of the typical crop production cycle of field preparation, planting, spraying and harvesting.
- Average annual precipitation has increased between 5 and 15%. Fall, winter and spring seasons are getting wetter and the summer is getting drier. Drier growing season will expand the need for irrigation.
- Increases in extreme precipitation events accelerates the degradation of critical soil and water resources. Excessive runoff erodes soil, reduces water quality, and damages infrastructure. Improved management practices are essential for building resilience to these challenges.
- Warmer spring and fall temperatures have expanded the growing season by 10 days but increased spring and fall precipitation have reduced the number of available field work days by the same amount, essentially offsetting the gain in the longer growing season.
- Warmer and shorter winters creates the opportunity for crop pests, pathogens and invasive plant species that are normally kept in check by cold temperatures to expand their ranges northward.
- Increase in summer high temperature creates health challenges to livestock.
- Warmer temperatures increase the potential for soil moisture stress and drought.
- Warmer summer night-time low temperatures negatively impact crop growth and yield and livestock production.
- More intense rain events require adaptation in row-crop agriculture to suppress soil erosion, including methods such as the use of cover crops, grassed waterways, water management systems, contour farming, and prairie strips.
- Farmers recognize that the climate is changing and are taking actions to try to mitigate the impacts.
- Based on temperature, humidity and precipitation, future summers in Ohio could resemble those in Arkansas and winters could be similar to those in Virginia.

REFERENCES USED

Andresen, J.A., S.D. Hilberg, and K.E. Kunkel, 2014. Historical climate and climate trends in the Midwestern United States. In: Climate Change in the Midwest: A Synthesis Report for the National Climate Assessment, J.A. Winkler, J.A. Andresen, J.L. Hatfield, D. Bidwell, and D. Brown (Eds.). Island Press. Pages 8-36.

Cheng, Muxi, Bruce McCarl, and Chengcheng Fei. 2022. "Climate Change and Livestock Production: A Literature Review". Atmosphere 13(1): 140

EPA. 2016. What Climate Change Means for Ohio. U.S. Environmental Protection Agency, EPA 430-F-16-037.

EPA. 2021. Seasonality and Climate Change: A Review of Observed Evidence in the United States. U.S. Environmental Protection Agency, EPA 430-R-21-002. www.epa.gov/climate-indicators/seasonality-and-climate-change.

Frankson, R., K.E. Kunkel, S.M. Champion, and D.R. Easterling. 2022: Ohio State Climate Summary 2022. NOAA Technical Report NESDIS 150-OH. NOAA/NESDIS, Silver Spring, MD, 5 pp.

Hatfield, J.L. 2014. Agriculture in the Midwest. In: Climate Change in the Midwest: A Synthesis Report for the National Climate Assessment, J.A. Winkler, J.A. Andresen, J.L. Hatfield, D. Bidwell, and D. Brown (Eds.). Island Press. Pages 70-82.

Hatfield, J. L., K. J. Boote, B. A. Kimball, L. H. Ziska, R. C. Izaurralde, D. Ort, A. M. Thomson, and D. Wolfe. 2011. Climate Impacts on Agriculture: Implications for Crop Production. Agronomy Journal 10(2) 351-370.

Hayhoe, Katharine, Jeff VanDorn, Vaishali Naik and Donald Wuebbles. 2009. Climate Change in the Midwest: Projections of Future Temperature and Precipitation. Union of Concerned Scientists, Cambridge, Massachusetts.

Intergovernmental Panel on Climate Change (IPCC). 2022. Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press.

Janowiak, M., D. Dostie, M. Wilson, M. Kucera, R. Howard Skinner, J. Hatfield, D. Hollinger, and C. Swanston. 2016. Adaptation Resources for Agriculture: Responding to Climate Variability and Change in the Midwest and Northeast. Technical Bulletin 1944. Washington, DC: U.S. Department of Agriculture.

Kling, G.W., K. Hayhoe, L.B. Johnson, J.J. Magnuson, S. Polasky, S.K. Robinson, B.J. Shuter, M.M. Wander, D.J. Wuebbles, D.R. Zak, R.L. Lindroth, S.C. Moser, and M.L. Wilson. 2003. Confronting Climate Change in the Great Lakes Region: Impacts on our Communities and Ecosystems. Union of Concerned Scientists, Cambridge, Massachusetts, and Ecological Society of America, Washington, D.C.

Seybold, Erin C., Ravindra Dwivedi, Keith N Musselman, Dustin W Kincaid, Andrew W Schroth, Aimee T Classen, Julia N Perdrial and E. Carol Adair. 2022. Winter runoff events pose an unquantified continental-scale risk of high wintertime nutrient export. Environmental Research Letters 17 (10): 104044. DOI 10.1088/1748-9326/ac8be5

Staudinger, M. D., T. L. Morelli, and A. M. Bryan. 2015. Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans. DOI Northeast Climate Science Center Report, Amherst, Massachusetts. Available at: http://necsc.umass.edu

Taber, S., Doidge, M., and Wilson, R. 2020. Farmer Adaptation to Changes in Extreme Weather: Survey Report. Columbus, OH: The Ohio State University, School of Environment & Natural Resources.

Upadhaya, S. and J.G. Arbuckle. 2021. Examining Factors Associated with Farmers' Climate-Adaptive and Maladaptive Actions in the U.S. Midwest. Frontiers in Climate 3:677548.

Wilson, Aaron. 2023. Personnel communication with Aaron Wilson, State Climatologist of Ohio; Assistant Professor - Ag Weather and Climate, Field Specialist, Department of Extension - CFAES.

Winkler, J.A., J.A. Andresen, J.L. Hatfield, J.L., D. Bidwell, and D. Brown (Eds.). 2014. Climate Change in the Midwest: A Synthesis Report for the National Climate Assessment. Washington, DC: Island Press.