Science Societies

Climate change indicators in agriculture and how CCAs can support growers

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This past summer (2020), the USDA released a report, *Climate Indicators for Agriculture*, that looks at 20 indicators, or measurements, of the influences of climate change on U.S. agricultural production. Among the goals of this report, USDA aimed to document how climate is affecting agricultural production and to identify research that can enhance the capabilities of the agricultural systems to increase production, reduce costs, and improve efficiency. The indicators described in the report were obtained in three ways—direct measurements, modeled, or derived from observations or model results—and fall into five broad categories: physical, biological, crop and livestock, phenological, and socioeconomic.

The following, drawn from the USDA report, focuses on climate indicators directly related to U.S. commodity crop production and offers ways CCAs can help their grower-clientele become more resilient in the face of changing climate and the resultant impacts on local weather, natural resources, pests and diseases, and farm management and operations. Fortunately, many of the crop management options that build farm resilience to climate change also have potential to mitigate climate change by drawing down and/or sequestering atmospheric carbon, the greenhouse gas which is the primary driving force behind anthropogenic climate change.

Physical Indicators of Changing Weather and Natural Resources

*Grain bin damaged by August derecho in Iowa. Source: **weather.gov**.*

Climate change drives changes in the physical environment, including weather and natural resources, which directly impact agricultural production. Farmers across the United States have witnessed firsthand many extreme weather events in recent years. Two recent examples include the historic flooding along the Missouri River and its tributaries in the Great Plains during the spring of 2019, which caused catastrophic crop losses, and the "derecho" this past August in Iowa that injured 40% of the state's corn and soy with winds gusting up to 112 mph.

Extreme precipitation in the form of heavy downpours can lead to myriad problems for crop production. Unfortunately, the frequency and intensity of these extreme precipitation events are increasing across the country (Easterling & Fahey, **2018**). Flooded fields can drown existing crops and delay access to fields for planting, harvest, and crop management. In contrast, lack of rainfall, particularly over long periods of time, can cause crops to wither and die in the field if irrigation is not available to make up for the shortfall. Rainfall occurring outside of the crop growing season is also problematic. With no crops to intercept rainwater, or rain falling on frozen ground, soil can be lost from fields, harming both farm productivity and water quality.

Soil moisture is the plant-available water found in the rhizosphere and is affected by meteorological factors like precipitation and evapotranspiration as well as soil characteristics like texture, structure, and organic matter content. In regions experiencing too much or too little precipitation, loss of crop productivity can be significant.

Nighttime air temperatures have been increasing for many years across the U.S. Warm nights negatively affect pollen viability, shorten the period of grain filling, and reduce crop yields. These undesired impacts of higher nighttime air temperatures have been documented for corn, soybeans, wheat, and rice. In the southeastern United States, the number of nights with minimum temperatures above 70°F have doubled in the past 50 years.

Heat waves, when high temperatures persist for several consecutive days, are projected to become more frequent, intense, and longer lasting. In the Southeast, heat waves tend to occur combined with higher humidity, leading to increased plant and animal stress and danger for agricultural workers. In the Southwest, heat waves are often accompanied by drought, resulting in crop failure.

Humidity, measured as dew point temperature, has been increasing. Higher dew point temperatures cause nighttime temperatures to climb and lead to increased incidence of plant diseases. Furthermore, high humidity poses challenges to drying and storage of commodity crops. Research has documented that land use changes—for example, converting a rangeland to row crop production—and cropping practices—such as irrigation or tile drainage—can have an influence on evapotranspiration and humidity of a region.

Biological Indicators of Changing Pests and Diseases

Changes in weather and natural resources also influence pest and disease pressure. Higher temperature and humidity over longer time periods create favorable environments for harmful weeds, insects, and microbes, which negatively impact productivity and may lead to increased pesticide use.

Warm-season weeds, like Palmer amaranth and kudzu, are migrating into areas that were previously too cold for them to colonize. This is particularly concerning because Palmer amaranth is resistant to multiple herbicide modes of action and kudzu is the alternate host to several soybean diseases.

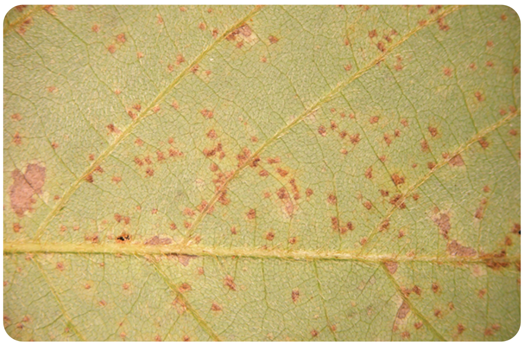
Like weeds, insect pests are also expanding their range as a result of higher temperatures. Additionally, higher temperatures allow insect pests to develop faster and produce more generations per year. In some areas, crop pests like corn earworms are able to survive and overwinter when historically they would have been killed off by cold temperatures.

Crop diseases caused by bacteria, fungi, viruses, and oomycotes (including *Phytophthora* and *Pythium* species) are spreading as temperatures increase worldwide. Eighty percent of major crop disease types have been migrating from the equator toward the poles at an average rate of 3 km/yr for the past 60 years.

With increased pest pressure, pesticide use is projected to increase, thereby raising production costs and increasing the risk of developing pest resistance to available chemical interventions. The efficacy of some herbicides has also been demonstrated to decrease at higher temperatures, limiting the available tools for farmers to address increasing pests and diseases.

Crop and Phenological Indicators of Agricultural Change

How we farm now and in the future is greatly impacted by climate change. As many areas of the U.S. previously considered marginal became productive cropping regions due to advances on irrigation, machinery, and crop varieties, current high-producing areas may experience a cropping system shift due to higher incidence of heat, drought, or reduced supply of irrigation water. The physical and biological indicators described above strongly influence crop development and management, forcing farmers and the agricultural communities that support them to adapt alongside them.



Soybean rust on kudzu. Source: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, ***Bugwood.org****.*

Crop indicators of agricultural change include longer leaf wetness duration (LWD) and shifting crop growing regions. Leaf wetness duration is the length of time free water is available on the surface of crop leaves and is affected by precipitation, dew point temperature, and soil moisture. Longer LWD increases crop vulnerability to water-loving disease organisms. Increasing nighttime temperatures, described in the "physical indicators" section above, coupled with higher humidity, suggest that changes in LWD can also be expected.

Pests are not the only ones with shifting distributions because of climate change. Crop growing regions are shifting and generally not for the better. By 2050, it will be difficult to grow corn in most of Kansas and large parts of Oklahoma, Missouri, Nebraska, North and South Dakota, and Texas, while yield losses of 5–25% or more can be expected in the rest of the Midwest and Mid-Atlantic. These shifts in crop growing regions may bring major economic disruptions for farmers and their surrounding communities, even as new opportunities for corn growers can open up for those at the highest latitudes of Minnesota, Wisconsin, Michigan, and New York.

Seed genetics are key to crop performance amid the many challenges posed by climate change. Source: United Soybean Board.

Phenological indicators, or those related to the timing of biological cycles, are especially impacted by climate. Warmer weather may lead to earlier bloom and earlier emergence of crop pests. Earlier bloom can negatively impact both pollinators and pollination if bee emergence in the spring does not correlate closely with flower emergence. Asynchronicity of bee emergence and pollination would present a serious challenge to agriculture. Another concern is that higher temperatures will likely result in extra generations of damaging pests during a growing season. Additional pesticide applications to bring these growing insect populations under control will not only increase the carbon footprint of agriculture but may make insecticide resistance more likely to develop, showcasing how the effects of climate change can set off compounding challenges for farmers.

Supporting Farm Resilience to Climate Change

Farmers are already facing the effects of climate change in their operations. As advisers work to support farmers to face these challenges, we can turn to agronomic practices that have been demonstrated to build soil health and farm resilience to climate change. Some of these practices, and the systems they create when used in combination, may help reduce atmospheric CO_2 and store carbon in soils in addition to strengthening farmers’ resiliency.

The following addresses some of the benefits of these practices and systems.

Integrated Pest Management

More and different pest pressure is one of the most obvious consequences of climate change for farms; it is projected that climate will influence pest incidence, abundance, and damage. Using an integrated approach to managing new or persistent pests reduces the need for pesticide application by using a suite of methods for prevention, early detection, and effective intervention with minimal impacts on human health and the environment. Without the ability to rely on long, cold winters to naturally manage certain pests, there is a risk for over-reliance on certain pesticide modes of action, which could lead to pest resistance. Moreover, the projected scenario of warmer winters poses the challenge of crop and livestock pests migrating northwards, and there is growing evidence that warmer temperatures coupled with rising atmospheric CO_2 levels result in decreased pesticide efficacy.

Cover Crops

While cover crops are not a "silver bullet" for climate change resilience and mitigation, the benefits of incorporating them into rotation are well documented. Maintaining living roots in soil and vegetative cover on top of soil is important for minimizing soil losses after heavy downpours. And by keeping soil covered, cover crops can help reduce weed pressure by preventing seeds from making soil contact and becoming established in the field. Although cover cropping is becoming

Using minimum tillage (shown here) or eliminating it altogether reduces soil compaction, improves soil structure, and creates a good seed bed. Copyright: Natural England/Peter Roworth. Source: ***Flickr.com****.*

more widespread, many growers need technical expertise on selecting seed and managing and terminating the cover crop. Cereal rye is likely the most popular cover crop; however, there are many alternative species from the cereals, brassicas, legumes, and other broadleaf families that can be included as a cover crop to most crop rotations.

Seed Selection

Seed genetics are key to crop performance amid the many challenges posed by climate change. However, it is projected that abiotic stresses brought by climate change, particularly higher temperature and water stress, will negatively affect seed quality. Not only will the seed industry need to adapt, by moving production sites and finding traits that help with changing climate conditions, but producers will as well, by modifying planting and harvest dates and the types of varieties adapted for each region. Disease resistance, heat and drought tolerance, and days to maturity are examples of traits that may be selected to protect yields in hotter, drier, or wetter conditions. Communicating results from annual variety trials conducted by the nearest land grant university to the growers you serve is a first step in helping them choose the best seed for their rotation.

Precision Irrigation

As drought conditions worsen and spread, particularly in the western United States, the need for irrigation technologies that wring value from every drop of applied water is growing. Increased awareness of water conservation needs and litigation due to short water supplies may make precision irrigation more economically feasible than it is now. Farmers need a tremendous amount of technological support and expertise to design and install complex systems that use soil sensors, weather stations, satellite imagery, scheduling software, and an array of components for precisely delivering the right amount of water in the right place at the right time.

No- or Reduced-Till

Reducing or eliminating tillage altogether may be a successful and practical approach for building soil health and resilience to climate change, along with saving time, fuel, and equipment maintenance needed for field operations. Leaving at least 30% of crop residues on the soil surface has demonstrated benefits for protecting against water and wind erosion. In drought-prone areas, avoiding soil disturbance reduces direct water evaporation and need for supplemental irrigation. Research has shown that aggressive spring tillage reduces soil water availability by 0.80-1.2 acre-inches in the seed zone, and it exacerbates the need for irrigation or precipitation after planting to replenish soil water lost.

Conclusion

Climate change presents extreme threats to farmers, their communities, and the food and agriculture industry. In the face of these challenges, we know that farmers are resilient and adaptive and that there are opportunities for advisers and the broader industry to support farmers in increasing their long-term resiliency through climate-smart practices.

Many of the best agronomic practices that can be implemented by the growers we serve not only improve individual growers' resiliency, but also offer long-term carbon sequestration benefits. Certified Crop Advisers and other trusted advisers can seize this opportunity to support growers in understanding and adopting science-backed conservation practices to ensure they are able to face the impacts of climate change and continue producing the food, fiber, and fuel we all rely on.

References

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