Heat stress to bring big changes to the US corn belt

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Climate change will bring new challenges for farmers as growing zones shift, and preparing for these shifts is vital for future food security worldwide. New research from UConn Department of Civil and

Environmental Engineering and Center for Environmental Sciences and Engineering researchers Meijan Yang and Professor Guiling Wang suggests that as the climate changes, we will see crop yield changes in one of the most productive growing regions in the United States. The study is published in Agricultural Systems.

Most of the corn and soy production in the U.S. is concentrated in a region of the Midwest known as the Corn Belt. With rich soil, coupled with a steady advancement of agricultural technologies over the past couple of centuries, the pace of increase in yield has been high.

"If you look at the long-term trend, yield has grown continuously, except for years with extreme events such as flood or drought. For example, in 2012 extreme droughts caused a huge drop in yield and set a record high for food prices. In the U.S. and elsewhere, this trend of increasing yield is because of technology, irrigation, and improved seed lines for example. The trend will be different in the future as climate changes," says Wang.

The researchers used a process-based model called the Decision Support System for Agrotechnology Transfer to simulate how different crop physiologic processes respond to environmental conditions like the amount of sunlight, precipitation, temperature, and humidity on each day through the growing season under a given climate. The model then determines the yield at the end of the growing season for each crop. To assess climate change impact, they conducted simulations for historical and projected future climates.

For the climate information, Wang explains they used the downscaled and bias-corrected data for ten models in the CMIP5 (Coupled Model Intercomparison Project Phase 5) from the MACA-2 (Multivariate Adaptive Constructed Analogs) database, which provides the fine resolution (at 4km) needed to assess local changes in climate.

The researchers found a northward shift of the most productive growing zones.

"When we look at past yield variability, the worst years are those with both drought and heat waves. The two tend to occur simultaneously because they really feed upon and reinforce each other," says Wang.

These compounding factors make it difficult to attribute crop yield loss to a specific stress based on statistical analysis as in previous studies, explains Wang, and this is where the power of the process-based model comes in because it accounts for the impacts of each stressor at the process level and can give a clear picture of how multiple stressors work in concert to impact yields.

"Using a process-based model allows us to quantify how much of the projected yield change comes from water stress and how much of it comes from heat stress and other stressors. Historically, most of the yield in the Corn Belt is limited by water stress," says Wang.

The researchers found that yield for maize and soy continues to be limited primarily by water stress until the 2040s and 2050s; but after mid-century, heat becomes the primary stressor and limiting factor, something farmers have not had to contend with in the past.

"This finding has implications for crop breeding. Right now, and in the near term, drought-resistant crops are important, but when you look at the long term, we need heat-resistant crops," Wang says.

Another point the researchers noted is that maize and soy do not follow the same trends in yield, owing to the differences in their photosynthetic strategies and optimal temperature. Some plants will benefit from the increases in CO_2, whereas others will reach a saturation point sooner and receive little or no benefit from the CO_2 fertilization effect.

Soybeans are one plant species that will benefit from the increase in CO_2 and temperature. The models show, with high agreement, that soybean yield will stay at the current level or increase by mid-century, but later in the century, the agreement is less certain, with some showing significant decreases. However, ultimately, the impacts of water and heat stress will counteract the CO_2 fertilization effect.

"The two crops show different patterns of change. Soy yield is projected to increase by mid-century with a northward expansion of the productive zone, but by late-century, we will start to see large decreases in the southern states and smaller increases in the Northern states," Wang says. "With maize, for both the middle century and late century, there will be a northward shift in the productive growing zone."

This amounts to about a 40% reduction in maize yield by the late century, and around 22% for soy. Wang also says the shift of the productive zone to the northern states is not sufficient to compensate for the loss in yield from the south. It also does not account for the feasibility of land use changes needed to accommodate the shift in the growing zone.

"As climate changes, farmers will not sit back and let this happen," says Wang. "For climate adaptation, heat-resistant crops will certainly help. Another strategy is to plant crops earlier."

The researchers included this planting time shift in the experiment and found that the strategy does mitigate a fraction of the negative impacts of climate change in some of the southern states, but it also cannot completely compensate for the loss of yield. Another strategy is irrigation to help with water stress, but Wang says the more difficult problem to address is heat stress.

"We will continue to see some yield increase, but that increase is going to happen at a much slower pace than what we have been used to, because climate change is going to offset the yield increases brought by technology," says Wang. "Looking at the future, we will have these shifts of the productive zones, and that means if we want to maximize the production system, it must migrate with the climate. Are people ready to do that?"

More information: Meijian Yang et al, Heat stress to jeopardize crop production in the US Corn Belt based on downscaled CMIP5 projections, *Agricultural Systems* (2023). DOI: 10.1016/j.agsy.2023.103746

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