Warming climate to result in reduced corn production; irrigation expected to blunt effect

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Researcher Suat Irmak programming the datalogger in one of his surface water vapor and energy flux towers to measure crop water use, all incoming and outgoing radiation fluxes, and all other climate variables such as air temperature, relative humidity, vapor pressure deficit, net radiation, precipitation, soil moisture, soil temperature on an hourly basis. The same flux tower was used in this corn vs. climate change study. Credit: Suat Irmak research group. All rights

No matter which of the widely accepted global circulation models ultimately comes closest to predicting the amount of warming caused by climate change, corn production will be reduced, according to a new study by Pennsylvania State University (Penn State) researchers.

They evaluated the potential impacts of 18 warming scenarios, dictated by various atmospheric greenhouse gas concentrations, to determine the potential effects of future climate change on irrigated and rainfed corn yields from the 2020s through the 2090s. Although the research was focused on the U.S.Great Plains—in the heart of the nation's top corn-producing region—the results are believed to have global implications.

To estimate yields, researchers employed the AquaCrop model—a crop-growth simulation developed by the Food and Agriculture Organization of the United Nations—to assess the effect of environment and management on crop production, predicting yield response to water. The study site is representative of agricultural management practices in the region and represents the most densely irrigated area in the Central Plains, which is a subregion of the Great Plains.

Corn is susceptible to environmental factors such as increased air temperature, increased radiation, vapor pressure deficit and humidity change, according to lead researcher Suat Irmak, professor and head of the Department of Agricultural and Biological Engineering in the College of Agricultural Sciences. He and his team noted that irrigated yields will be impacted much less than rainfed yields.

"In our study, depending on the atmospheric greenhouse gas concentrations and associated level of warming, we saw declines in

rainfed corn yields ranging from 2.2% to 21.5%," he said. "Under those same greenhouse gas concentrations, the range of declines was lower for irrigated yields—from 3.7% to 15.6%, due to irrigation technologies providing more stable crop growth conditions under water- and temperature-stress."

Global climate is very likely to warm by 2.16-3.42 degrees Fahrenheit from now to 2040, according to the Intergovernmental Panel on Climate Change, Irmak explained. The global mean surface temperature was 1.78 degrees F higher during the period 2001–20 than during the pre-industrial period of 1850–1900, the United Nations panel found.

Previous research by Irmak and others has shown that climate change already has impacted crop productivity of major agricultural crops across global agroecosystems. Previously, Irmak found that due to the increase in air temperature, spring frosts are occurring earlier and fall frosts are occurring later. This results in increased growing season length up to 20-plus days, which has significant implications for agricultural production in the U.S. and globally.

The research is important, Irmak noted, because by many measures corn is the country's most important crop. According to the U.S. Department of Agriculture, corn accounts for 92 million acres of land use in the United States. With a continuous increase in air temperature and atmospheric moisture demand—coupled with increasingly limited water supply conditions and water quality degradation in the midwestern and western regions—we may see a substantial shift in corn production to eastern U.S. regions, he warned.

"These analyses can be valuable for policymakers, decision-makers and agricultural and water resource managers/professionals to evaluate the future tradeoffs among irrigation and rainfed yields," he said. "They need to know how landscapes are projected to perform under two

scenarios with respect to climate change."

In findings recently published in *Agricultural Water Management*, the researchers reported that, based on their modeling results, rainfed yields will decline up to 40 bushels per acre, whereas irrigated yields are projected to decline only 19 bushels per acre. Additionally, rainfed corn yield will be more variable than yields from irrigated corn under most of the global circulation models.

Those declines would be damaging because corn is substantially embedded into our lives, Irmak pointed out. It is used for animal feed, human consumption, fiber production and field production for ethanol. So, agricultural scientists need to analyze the anticipated losses in production and their implications, he suggested. "Climate change is real—that's the bottom line," he said. "We need to understand how this might impact our national policies and food supply."

Changes in climate characteristics are projected to manifest as increased mean air temperatures in most land and ocean regions, with hot extremes, heavy precipitation and increased probability of drought and precipitation deficits, Irmak added. Such climate shocks and shifts will impact crop yield, cultivation area and food supply, impacting sustainable agricultural development and poverty-eradication goals.

"But estimating the magnitudes of those changes is challenging because temperatures and precipitation have complex impacts on crop yields, along with other critical meteorological variables," he said. "It only can be done with appropriate crop models. We will be conducting similar long-term analyses for specialty cropping systems, including fruit trees and major row crops, in Pennsylvania as well."

This study is a part of long-term research investigating the fundamentals of coupled climate change and the impact of water, nutrient and crop-

management strategies on agroecosystem productivity and environmental relationships for cropping systems, which Irmak started at the University of Nebraska and continues at Penn State.

Contributing to research were Rupinder Sandhu and Meetpal Kukal, who both received their master's and doctoral degrees and worked as postdoctoral research associates under Irmak's supervision at the University of Nebraska. Kukal currently is a research assistant professor in the Agricultural and Biological Engineering Department at Penn State, and Sandhu works with Locus Agricultural Solutions.

More information: S. Irmak et al, Multi-model projections of trade-offs between irrigated and rainfed maize yields under changing climate and future emission scenarios, *Agricultural Water Management* (2021). DOI: 10.1016/j.agwat.2021.107344

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