TIM GREEN (D2564-1)

Hotter Summers Could Trump CO_2 Benefits on Dry Cropland

Reducing tillage is one major hope for salvaging some of the crop yield losses predicted for the semi-arid Central Great Plains due to climate change—as well as for conserving water as supplies decline.

That's one finding from an innovative Agricultural Research Service study that combined a computer model with 15 to 17 years of field crop and climate data—and Colorado Water Conservation Board global change projections for Colorado through the year 2050. The board made a synthesis summary of climate change for Colorado from projections of 16 different global climate change models for three greenhouse gas emission scenarios, reported by the United Nations Intergovernmental Panel on Climate Change in 2007, and other climate change reports for Colorado.

The multi-model average projections call for an increase in equivalent carbon dioxide (CO_2) levels from 380 parts per million (ppm) in 2005 to 550 ppm by 2050. They also call for Colorado's summer temperatures to rise by about 5°F by 2050. The scientists in the ARS study extrapolated the projections to the year 2100 by assuming a linear increase of CO_2 and temperature.

The Colorado climate projections through 2050 came from a report commissioned by the board and carried out by the University of Colorado-National Oceanic and Atmospheric Administration Western Water Assessment.

Rare Look at Global Warming Effects on Crop Rotations

Research leader Laj Ahuja and colleagues at the ARS Agricultural Systems Research Unit at Fort Collins, Colorado, used the Root Zone Water Quality Model, version 2 (RZWQM2), for their computer model runs. They superimposed the multi-model average climate projections onto data from 15 to 17 years of experiments with three crop rotation systems—wheat-fallow, wheat-corn-fallow, and wheat-corn-millet—to see how yields might be affected in the future.

They simulated different combinations of three climate change projections: rising CO_2 levels, rising temperatures, and a shift in precipitation from late spring and summer to fall and winter. They ran the model for each of the 15 to 17 years of available crop data for each cropping system.

All Yields Down

They found that when all three factors were combined in a model run, yields of all crops went down in all three cropping systems, progressively to the year 2100. The decline in corn and millet yields was more significant than that in wheat yields. Ahuja says the data suggests that the temperature increase would decrease growth of plants while increasing their potential demand for water.

Left: This dome is a weather facility at Greeley, Colorado, one of many stations that gather multiple years of climate data used in combination with a model to project future crop yields in response to various climate changes.

"The negative effects of warmer temperatures would outweigh the benefits of higher atmospheric CO_2 on all the crops in the rotations. High levels of CO_2 enhance photosynthesis in crops like wheat and help plants retain water by causing the stomatal pores on their leaves to partially close," Ahuja says.

Ahuja did the study with colleagues at Fort Collins, including Jonghan Ko—an agronomist/computer modeler who is now at Chonnam National University in Gwangju, South Korea—and David Nielsen, an ARS agronomist at Akron, Colorado.

The crop data came from field crop experiments that are ongoing at the ARS Central Great Plains Research Station in Akron, involving rotations of wheat and other crops.

Ahuja also simulated yields of the three crop rotations over the past 96 years of climate data, looking only at CO_2 effects, from 300 ppm in 1912 to the current level of 380 ppm. That data, too, came from the Akron station, which was established by the U.S. Department of Agriculture in 1907.

"This study allowed us to doublecheck the effects of high CO_2 over nearly a century of climate data, with actual rather than projected fluctuations in precipitation and weather," Ahuja says.

They found that the higher CO_2 increased yields of wheat and millet, but not corn.

Models and Long-Term Data Best for Predicting Climate Change Effects

"Calibrating computer models like RZWQM2 with long-term field and climate data provides the best way to predict the effects of climate change and the farming strategies that will make the best use of limited water," Ahuja says. "Climate change will only make water scarcity worse for farm crops like wheat, corn, or millet in areas like the semi-arid Central Great Plains.

"Although the results of this study only apply to nonirrigated crops in the central Great Plains, the technique could be used elsewhere in the country with different crops, with or without irrigation."

Ahuja and colleagues used a hybrid version of RZWQM2, adjusted to the better data acquired in wheat FACE (Free Air Carbon Enrichment) and T-FACE (Temperature Free-Air Controlled Enhancement) experiments at the ARS Arid-Land Agricultural Research Center in Maricopa, Arizona. This data gives a more accurate accounting of the enhanced photosynthetic growth effects from higher CO_2 levels. It also adjusts for the water-saving effects of higher CO_2 levels.

Ahuja and colleagues released the original Root Zone Model in 1992 and, in 2007, released an improved version that links to better crop-growth models.

No-Till Helps—To a Point

Ahuja simulated changing planting dates up to a month earlier and using no-till to see whether either option would ameliorate yield losses, but only the no-till option helped. No-till leaves crop residue on the field after harvest, forming a protective layer that reduces evaporation and helps the soil retain water.

"In the wheat-fallow rotation with no tillage, wheat yields were higher than with conventional tillage through 2075," he says. "This shows that crop rotation and tillage practices have a greater effect on yields than any 'advantages' that might be offered by climate change, such as growth-boosting and water-saving effects from CO_2. When summer temperatures reached 8˚F warmer in 2100, even the no-till yield advantage was lost.

"This is a unique study of the effects of climate change on three crop rotations. As far as I know, this is the first study of climate change effects on millet," Ahuja says.

New Crop Varieties Answer in Long Run

"There is always room for improvement," Ahuja says. "For example, the computer models currently don't account for new crop varieties that are better adapted to climate change or for crops' possible natural adaptations—within each variety—to conditions over time. We could improve accuracy by using more complete and detailed models of crop photosynthesis and transpiration. And we have to develop better ways to downscale global climate change prediction data to fit specific regions, especially for a state like Colorado whose climate is made highly variable by the varying elevations of the Rocky Mountains. For now, no-till provides one answer for some crops. For the long run, breeders and geneticists will have to develop varieties that can tolerate higher temperatures or change to crops that are both high-temperature and drought tolerant, such as replacing corn with sorghum."—By **Don Comis,** formerly with ARS.

This research is part of Water Availability and Watershed Management (#211) and Agricultural System Competitiveness and Sustainability (#216), two ARS national programs described at www.nps.ars.usda.gov.

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The data from this FACE (Free Air CO_2 Enrichment) experiment was used to validate the model for CO_2 effects on plant growth.

BRUCE KIMBALL (D2563-1)