# Lost freshwater may double climate change effects on agriculture

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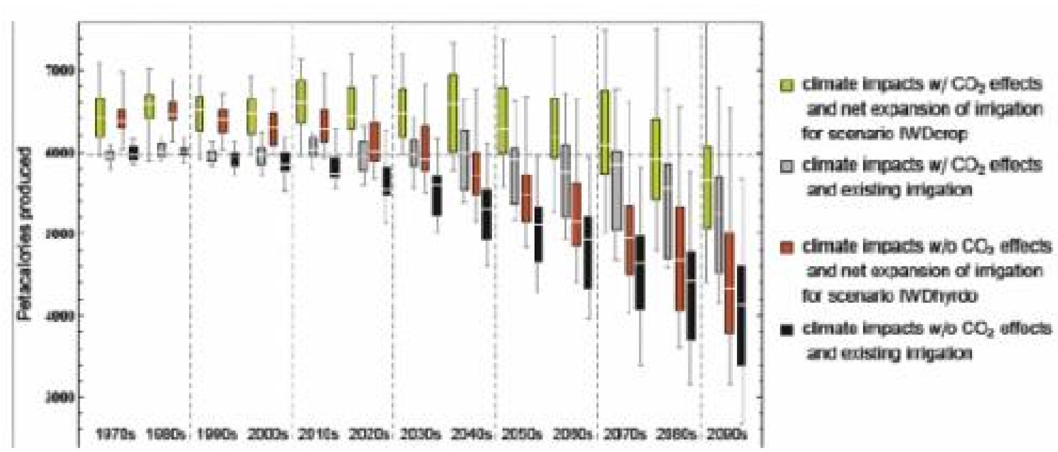


Comparison of the total annual global calories of maize, soybean, wheat, and rice for RCP 8.5 as projected by four sets of ensemble simulations. Credit: Elliott et al, 2013.

A warmer world is expected to have severe consequences for global agriculture and food supply, reducing yields of major crops even as population and demand increases. Now, a new analysis combining climate, agricultural, and hydrological models finds that shortages of freshwater used for irrigation could double the detrimental effects of climate change on agriculture.

Given the present trajectory of greenhouse gas emissions, agricultural models estimate that climate change will directly reduce food production from maize, soybeans, wheat and rice by as much as 43 percent by the end of the 21st century. But hydrological models looking at the effect of warming climate on freshwater supplies project further agricultural losses, due to the reversion of 20 to 60 million hectares of currently irrigated fields back to rain-fed crops.

"It's a huge effect, and an effect that's basically on the same order of magnitude as the direct effect of climate change," said Joshua Elliott, a research scientist with the Computation Institute's Center for Robust Decision Making on Climate and Energy Policy (RDCEP), Argonne National Laboratory, and lead author of the paper. "So the effect of limited irrigation availability in some regions could end up doubling the effect of climate change."

The research was led by Elliott and colleagues from the Agricultural Model Intercomparison and Improvement Project (AgMIP), as part of the Inter-Sectoral Impacts Model Intercomparison Project (ISI-MIP). The paper is among 12 featured in a special feature dedicated to ISI-MIP research in *Proceedings of the National Academy of Sciences*, published online December 16.

Agricultural models and hydrological models both incorporate the influence of climate, but are designed by different scientific communities for different purposes. While agricultural models simulate how temperature, precipitation and other climate factors may alter the yield for various crops, hydrological models seek to estimate water-related characteristics such as stream flow, water availability, and storm runoff.

The two types of models overlap in estimating the amount of water used for agricultural irrigation, by far the largest human use of freshwater in the world. But when Elliott and colleagues fed each type of model with the same climate model forecasts, the models produced dramatically different predictions about the future demand for freshwater irrigation

The researchers discovered discrepancies in how hydrological models incorporate processes such as the carbon cycle and crop water productivity when compared to agricultural models – a finding that will help make existing models more accurate.

"This is absolutely the first study in which a multi-model ensemble of hydrological models was compared to a multi-model ensemble of crop models," Elliott said. "Several modeling groups have already changed the way that they are modeling the hydrological cycle with respect to crops because of the results of this paper."

The comparison also produced new insight about the potential agricultural consequences of climate change. Due to climate change alone, the models predicted a loss of between 400 and 2600 petacalories of food supply, 8 to 43 percent of present day levels. But due to the decline in freshwater availability – and the associated conversion of irrigated cropland to rain-fed – the models predict an additional loss of 600 to 2900 petacalories, the researchers discovered.

However, while the models predict freshwater shortages in some areas of the world, such as the western United States, India and China, other regions may end up with a surplus of freshwater. Redistributing that excess water to restore or add irrigation to rain-fed crop areas could dampen some of the consequences of climate change upon irrigation and agriculture, Elliott said.

"We found that maximal usage of available surplus freshwater could end up ameliorating between 12 and 57 percent of the negative direct effects of climate change on food production," Elliott said. "However, there are lots of different political, economic and infrastructural reasons why you would consider that to be overly optimistic."

The results are among several major findings reported in the ISI-MIP special issue of *PNAS* by the AgMIP group, which conducted a "fast-track" exercise to generate new knowledge about climate change impacts on agriculture for the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

"Understanding the climate change implications of freshwater availability is key to the future food security goals of society," said Cynthia Rosenzweig, co-primary investigator of AgMIP and co-author of the paper. "The rigorous AgMIP multi-model approach is enabling advances in research on how climate change will affect agriculture worldwide and water is a vital component."

**More information:** "Constraints and potentials of future irrigation water availability on agricultural production under climate change." Joshua Elliott, Delphine Deryng, Christoph Müller, et al. *PNAS* December 16, 2013, DOI: 10.1073/pnas.1222474110

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