Future rice yield losses due to climate change could be extreme

Climate warming poses a major threat to rice's role in our global food security.

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Rice is a staple food for more than half of the world’s population. Rice yields depend on numerous factors, such as agricultural practices, but they also depend on the temperature at which the crop is grown. Previous studies have shown that temperatures above rice’s optimum physiological temperature can reduce crop yield.

As a result, the International Food Policy Research Institute has stated that the effects of rising temperatures from climate change would likely reduce rice yield by 10 percent by 2050. This could have dramatic impacts across the world, as hunger and malnutrition are already significant problems.

But little is known about the physiological mechanisms through which rice plants respond and adapt to climate change. Previous investigations have left a lot of uncertainty, as they've used different methods to develop crop models. To address this, an international team of scientists has explored how rising temperatures affect the sensitivity of rice yields using a new compilation of data from 83 field warming experiments at 13 sites across the globe. The team also evaluated three
modeling approaches (statistical models, local crop models, and global gridded crop models) to understand one of the sources of uncertainty.

**Crop model predictions**

The team ran five crop models (global gridded crop models) with daily weather outputs generated by five representative high-warming climate models; all of these set carbon dioxide emissions at the present day value (excluding relevant benefits from carbon dioxide fertilization in the future), meaning carbon would continue to accumulate in the atmosphere throughout the century. This procedure enabled the team to isolate the influence of climate warming on rice yield. The climate models predicted an increase in the mean air temperature of 3.3 to 5.0 Kelvin over rice-growing areas during growing season.

The median value of the climate-induced rice yield change that resulted was -27 percent. That’s a dramatic decrease compared to today, and it would put global food security in significant danger. But the drop ranged from 6.6 percent to 42.4 percent, primarily due to the significant uncertainty inherent in climate predictions. This range encompasses everything from an utter disaster to problems that could be compensated for by improved agricultural practices.

The team also determined the sensitivity of the rice yield to warming by the end of the 21st century. The long-term sensitivity essentially indicates how much the yield will change per degree of temperature change (in this case, degrees Kelvin) above present-day values. The team found that all combinations of the crop models and climate models yielded drops between 1.3 and 9.3 percent for each Kelvin of climate change. (Note that the temperature is expected to change by several Kelvin under business-as-usual emissions.)

**Comparisons**

The scientists assessed the validity of their model predictions using real-world data. In field experiments, rice lots have been warmed during the crop cycle, and the effects on yield were recorded. More than 80 percent of the 83 field experiments exhibited a rice yield loss under warming conditions. On average, the rice yield dropped by 5.2 ±1.4 percent for each Kelvin of warming. When the field experiment data was taken into account, it reduced the error on the maximum likelihood value of rice's sensitivity to warming and made the effect more severe than the models alone predicted—a drop of 8.3 ± 1.4 percent per Kelvin. It also reduced the variation among the models by 33 percent.

Other publications have used local, rather than global, crop models to interpret field trials. These local crop models are often tailored to specific rice varieties and cultivation practices. Analyzing a number of local crop models, however, generated a similar impact on rice's sensitivity to climate change, with a drop in yield of 6.3 ± 0.4 percent for each Kelvin of change.

The outlier among the analyses performed in this paper are the statistical models, which predict rice yield sensitivity to temperature changes based on observed year-to-year variability. Statistical crop models suggest a minimal impact of warming on rice yields, with a drop of only 0.8 ± 0.3 percent for each Kelvin of temperature change. Global gridded crop models that compare present-day yields
and long-term trends are also less negative, predicting a drop of 2.4 ±3.7 percent for each Kelvin of temperature change.

Finally, the International Food Policy Research Institute has its own analysis, which projects a reduction of 4.2 to 6.4 percent for each Kelvin of temperature change.

This investigation suggests that future yield problems may be more significant than we'd been expecting. If that's right, the equally significant measures are likely required to prevent severe rice yield losses. Preventative measures such as genetic improvements that produce rice strains that are more tolerant of heat should be seriously considered to mitigate the risk inherent in the more extreme numbers seen here.