CLIMATE TRENDS AND GLOBAL CROP PRODUCTION SINCE 1980

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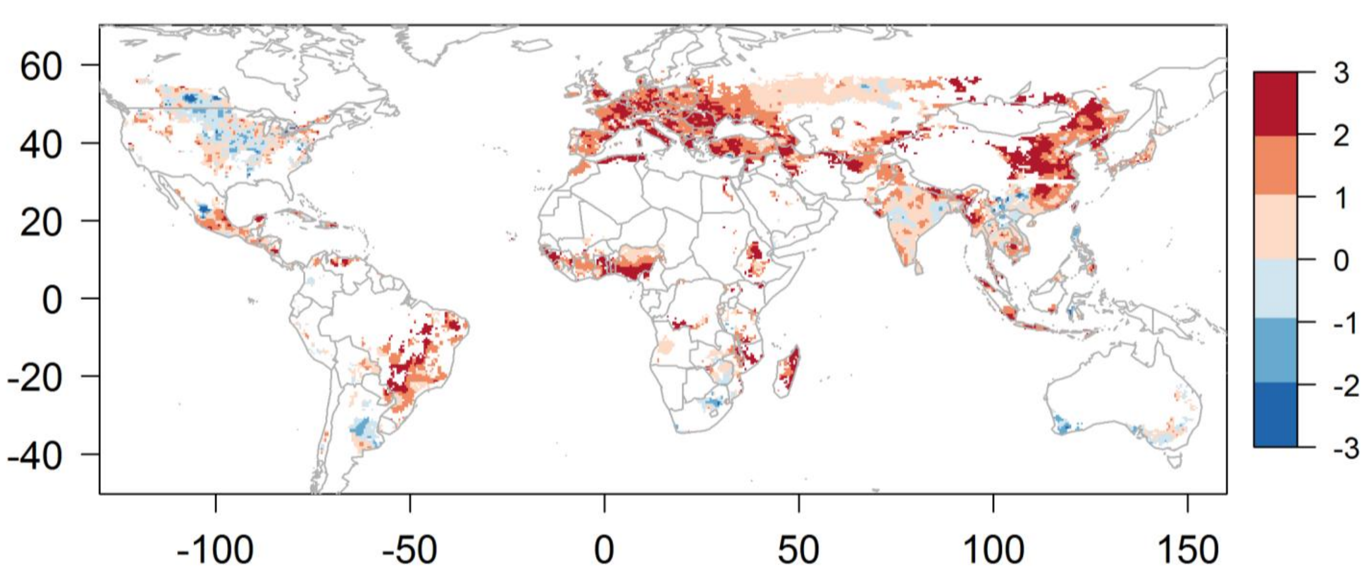
One way of understanding how climate change is likely to affect global food production and food security is to better understand the recent past. That is, how have changes already influenced agricultural activities and production? For example, considerable debate has taken place on whether future impacts in agriculture will be driven mainly by rising temperatures, or if instead precipitation changes are the main concern. The answer to this would influence strategies to adapt, such as investing in heat tolerance versus waiting for better rainfall projections. To inform questions such as these, we analyzed historical weather and crop data throughout the world over the past 30 years. From this analysis, we draw several conclusions that are relevant to policy makers.

Weather during the growing season is changing in many, but not all, of the places where crops are grown. Compared to historical year-to-year variability, growing season temperature trends are quite large in many regions (Figure 1). A notable exception is in North America, including wheat in Canada and maize and soybean in the United States. The study does not explain *why* trends are larger in some areas than others, but a substantial number of climate studies relate to this topic. In general, regional trends are affected by global forcings such as greenhouse gases, regional forcings such as aerosols, and natural variability in the climate system.

These changes are big enough to have significant effects on crop production in many regions. Although it is well known that weather affects crops, it is difficult to measure exactly how much these trends have mattered. Simply observing historical yields is easily misleading, because many factors other than weather change in time. Instead we must rely on models to estimate how much the observed weather changes have mattered. Among the biggest losers from recent trends appear to be wheat in Russia, India, and France, and maize in China and Brazil. The United States has experienced very small impacts on maize, soybean, or wheat. Globally, we estimate that maize production would be roughly 6% higher and wheat production 4% higher had agriculture not been exposed to climate trends since 1980. Effects on rice and soybean were lower and not statistically significant.

Figure 1. Observed changes in growing season temperature for crop growing regions for 1980-2008. Values show the linear trend in temperature for the main crop grown in that grid cell, and for the months in which that crop is grown. Values indicate the trend in terms of multiples of the standard deviation of historical year-to-year variation. A value of two, for example, indicates that the expected growing season temperature in 2008 was two standard deviations above the expected value in 1980. Grid cells with less than 1% of land area covered by maize, wheat, rice, or soybean, are omitted for clarity.



Temperature trends have dominated the effects of rainfall trends in most cases. This is because precipitation has shown large changes in only a few countries. In fact, in these countries the changes in rainfall have been more important to agriculture than warming, but in most regions, the warming effects are much more important. Globally averaged, effects of changes in growing season average rainfall are near zero. These results imply that efforts to adapt national production to climate change should focus primarily on heat-related impacts, and that refining rainfall uncertainties may be less of an obstacle to anticipating impacts at these scales than implied by some studies.

Production effects have likely contributed in part to the rise in global food prices. The significant global effect on maize and wheat production has meant that global supply has risen slower than it otherwise would have. Using prior studies of economic responses to a shift in the supply curve, we estimate that the warming effects on production have led to a roughly 20% increase in global market prices for these commodities. If one accounts for the beneficial effects of increasing CO_2 during the study period (due to the fertilization effect) the net effect of climate and CO_2 changes has been a roughly 5% increase in prices. At current market prices and global production levels, this translates to roughly an additional $50 billion per year spent on food.

Caveats and future work. There are at least two important caveats to our results. First, we only consider average growing season conditions, which ignores potential changes in within season variation. For example, the frequency of extreme rainfall events has been increasing in some regions, and this likely has a negative impact on crops that we do not capture here. Second, the study looks at weather changes over a fixed area for each crop-country combination, namely the areas where crops were growing circa 2000. If the location of crops has been changing significantly within countries since 1980, either as a response to warming trends or for other regions, the study would fail to capture the effects of these changes. Current work is focused on understanding the types of shifts that are occurring in rapidly warming regions, both in where and how different crops are grown.

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