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Climate change, biofuels, and global food security

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PERSPECTIVE

Climate change, biofuels, and global food security

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There is a new urgency to improve the accuracy of predicting climate change impact on crop yields because the balance between food supply and demand is shifting abruptly from surplus to deficit. This reversal is being driven by a rapid rise in petroleum prices and, in response, a massive global expansion of biofuel production from maize, oilseed, and sugar crops. Soon the price of these commodities will be determined by their value as feedstock for biofuel rather than their importance as human food or livestock feed [1]. The expectation that petroleum prices will remain high and supportive government policies in several major crop producing countries are providing strong momentum for continued expansion of biofuel production capacity and the associated pressures on global food supply.

Farmers in countries that account for a majority of the world's biofuel crop production will enjoy the promise of markedly higher commodity prices and incomes.[1] In contrast, urban and rural poor in food-importing countries will pay much higher prices for basic food staples and there will be less grain available for humanitarian aid. For example, the developing countries of Africa import about 10 MMt of maize each year; another 3–5 MMt of cereal grains are provided as humanitarian aid (figure 1). In a world where more than 800 million are already undernourished and the demand for crop commodities may soon exceed supply, alleviating hunger will no longer be solely a matter of poverty alleviation and more equitable food distribution, which has been the situation for the past thirty years. Instead, food security will also depend on accelerating the rate of gain in crop yields and food production capacity at both local and global scales.

Given this situation, the question of whether global climate change will have a net positive, negative, or negligible impact on crop yields takes on a larger significance because additional hundreds of millions of people could be at risk of hunger and the window of opportunity for mounting an effective response is closing. To answer this question, Lobell and Field use an innovative empirical/geostatistical approach to estimate the impact of increased temperature since 1980 on crop yields—a period when global mean temperature increased ~0.4 °C [2]. For three major crops—maize, wheat, and barley—there was a significant negative response to increased temperature. For all six crops evaluated (also including rice, soybean, and sorghum), the net impact of climate trends on yield since 1980 was negative.

While the approach used by Lobell and Field can be questioned on several points,[2] the body of their work represents an ambitious global assessment of recent climate impact on crop yields. Most noteworthy is their conclusion that: the combined effects of increased atmospheric CO_2 concentration and climate trends have largely cancelled each

[1] USA (40% of global maize, 56% of global maize exports), Brazil (33% of global sugar, 36% of global sugar exports), Indonesia and Malaysia (81% of global palm oil, 88% of global palm oil exports)—2005 data from FAOSTAT: http://faostat.fao.org/site/395/default.aspx

[2] For example, the use of a "global season" for calculating temperatures is problematic. In the case of soybean, a substantial portion of global soybean production occurs in the southern hemisphere, mostly in Brazil and Argentina, yet the global season for temperature was July–August—a time when soybean is not grown in these countries. Likewise the global season for rice was January–October, a period in which two consecutive rice crops are grown in tropical and subtropical irrigated systems of Asia—systems that account for a large portion of global rice production.

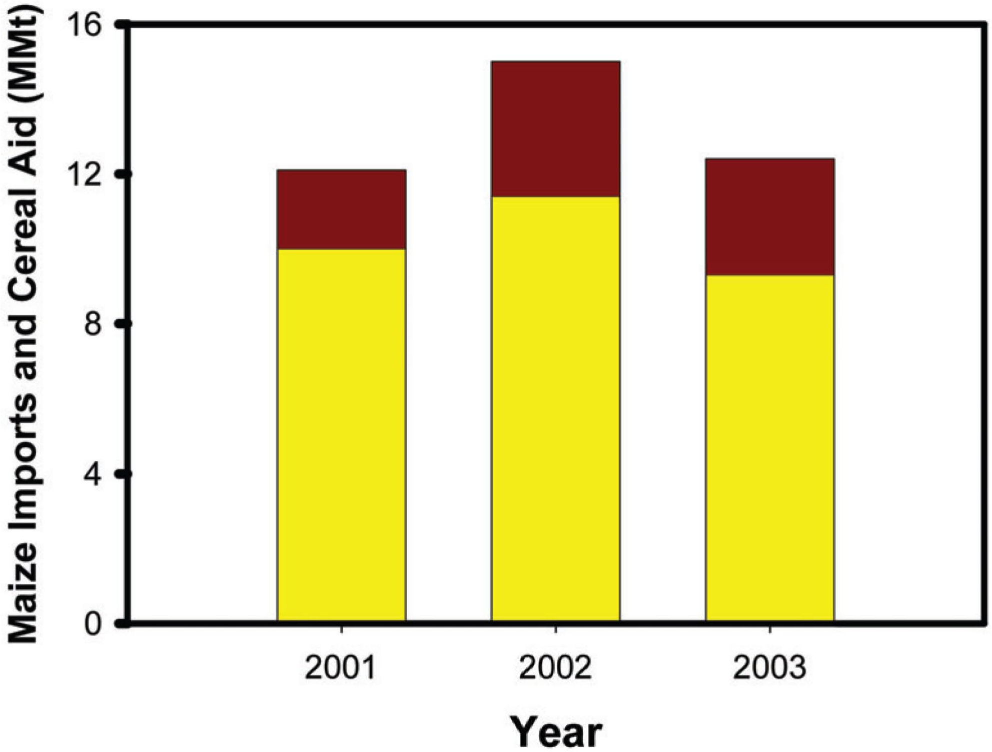

Figure 1. Maize imports (yellow bar) and cereal donations as humanitarian aid to the developing countries of Africa, 2001–2003. MMT = million metric tons.
Data source: http://faostat.fao.org/site/395/default.aspx

other over the past two decades. They contrast their finding with the conclusion of the International Panel on Climate Change (IPCC) that CO_2 benefits will exceed temperature-related yield reductions up to a 2 °C increase in mean temperature [3]. It should be noted, however, that the IPCC is coming out with a new assessment to be released in April 2007 (http://www.ipcc.ch/), and it remains to be seen if this conclusion still holds.

The purpose here is not to support or challenge the conclusions of either Lobell and Field or the IPCC, but rather to highlight the fact that there are substantive differences between results obtained from geostatistical assessments based on recent climate trends and actual crop yields versus assessments based on results from controlled experiments in growth chambers, greenhouses, and field enclosures and crop modeling. And while there appears to be good agreement on the predicted impact of atmospheric CO_2 enrichment on crop yields across a wide range of studies conducted using different approaches [4], there is less convincing evidence on the impact of warming temperatures.

There are three reasons for greater uncertainty about temperature effects. First, it is logistically more difficult to control temperature at elevated levels in studies that allow crops to grow in an "open-air" environment comparable to field-grown plants. The "free-air carbon dioxide enrichment" (FACE) systems were specifically designed to avoid such problems for study of CO_2 effects and appear to have been largely successful [4]. In contrast, growth chamber, greenhouse, and small-enclosure studies used for temperature-effect experiments have confounding effects associated with differences in humidity, air turbulence, and reduced light intensity that result from the need to more fully enclose experimental units with a transparent barrier to achieve adequate temperature control. Second, unlike CO_2 effects, yield response to temperature is often discontinuous. In many crops, pollination fails if temperatures rise above a critical threshold, which can result in dramatic yield reductions due to very small changes in temperature. Also, because climate change is predicted to increase both average temperature and temperature variability, changes in both factors must be evaluated in experiments with realistic growth conditions to fully understand climate change impact on crop yields. Such experiments would require expensive infrastructure with creative new designs—studies that have yet to be conducted, in part due to lack of adequate funding. A third factor is the interactive effect of temperature and plant nitrogen (protein) content on respiration, which is poorly understood.

In the absence of such studies, it is sobering to note that one long-term field study in which the effect of temperature on rice yield could be isolated from other factors documented a 15% decrease in yield for every 1 °C increase in mean temperature [5]. The magnitude of this decrease is considerably larger than predictions of yield decreases from higher temperature obtained from crop simulation models. Like the results of Lobell and Field [2], we see a discrepancy between estimates of the effects of warmer temperatures on crop yields based on the relationship between crop yields and temperature under field conditions versus those derived from modeling and experiments conducted under controlled conditions. As we make the historic transition from an extended period of surplus food production to one in which demand for staple crop commodities exceeds supply, there is a vital need to better understand the impact of warming temperatures on current and future crop yields.

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