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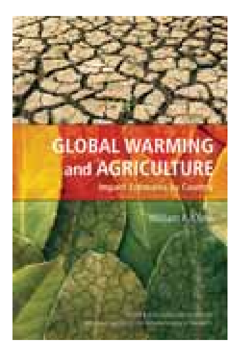
Why developing world agriculture stands to suffer big time.

Global Warming Losers

BY WILLIAM R. CLINE

Fifteen years ago the Institute for International Economics published my book, *The Economics of Global Warming.* In that study I made rough estimates of the damages that could be expected for the U.S. economy from long-term global warming. Agriculture was an important category in my list of expected losses, not surprisingly for anyone who has read John Steinbeck's *Grapes of Wrath* with its account of 1930s dust bowl conditions in Oklahoma and Arkansas. My estimates were based on EPA studies of agricultural impacts.

In recent years there has been a certain revisionism toward more benign diagnoses of prospective effects of global warming on agriculture. Some have argued that up to an additional 2°C or even 3°C in global mean surface temperatures would lead to global benefits rather than losses, because of improved growing conditions in cold regions and because of "carbon fertilization" from increased atmospheric concentrations of carbon dioxide (which is an input into the process of photosynthesis). At the same time, there has been a growing body of research indicating that the developing countries will be the ones to suffer most and earliest, because their predominantly



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low-latitude location makes their temperatures already close to or above levels at which additional warming reduces productivity.

Research findings in recent years have provided a growing base of model estimates that can offer the basis for a more comprehensive and systematic analysis of the impact of global warming on world agriculture than previously available. My new book makes such estimates for late in this century (the 2080s) at a geographically detailed level, with calculations for more than one hundred countries, regions, and sub-regions within the largest countries. This essay summarizes my findings and considers their implications for international policy.

The first question is whether the world as a whole faces devastating agricultural losses. The answer turns out to be no, at least in the central estimate: there would be aggregate losses on net, but they would be modest to moderate. The second question is whether the developing countries would be at risk. The answer is a definite yes, especially in South Asia, Africa, and Latin America. Yet even here it turns out that there is a major caveat: the most important developing country of all for global warming policy, China, is about neutrally affected overall (despite potentially sizable losses in its South Central region). As political leaders in developing countries become more aware of these prospects, divisions could develop among them on the urgency of international action.

Although the broad profile of these results is similar to the predominant evaluations in the Intergovernmental Panel on Climate Change, my study provides greater detail on a more systematic basis than previously available. It also takes account of both of the two alternative methods that have dominated past estimates, the crop-model approach and the so-called "Ricardian" agronomic estimates based on observed relationships of land prices to climate.

The first step in the analysis is to calculate detailed regional changes in temperature and precipitation to be expected from global warming. The IPCC provides data on the current climate at a detail of one-half degree latitude by one-half degree longitude (about 175,000 land-based "grid cells"). It also provides the results of six leading climate ("general circulation") models that indicate projected changes in temperature and precipitation at less-detailed geographical levels. I map each model's results to standardized detailed geographical areas and then take the averages to arrive at a "consensus climate projection." For this I use what I consider to be the most meaningful of the IPCC business-as-usual scenarios for carbon dioxide emissions ("A2," which calls for emissions to rise from about 7 billion tons of carbon annually today to about 30 billion tons by 2100 in the absence of abatement measures). The resulting consensus estimates place average land surface warming at about 5ºC by the 2080s.

My estimates then apply two families of agricultural impact models to calculate the corresponding results for world agricultural productivity. The first comprises the crop-model estimates developed at agricultural research stations around the world and compiled by Cynthia Rosenzweig at Columbia University and her colleagues. These models take account of the faster pace of growing cycles and hence lesser grain-filling at higher temperatures, along with greater heat and water stress. They incorporate moderate adaptation, such as a change in crop mix and planting dates and increased irrigation in existing systems.

The second is a set of "Ricardian" models developed by Robert Mendelsohn at Yale University and associated researchers at the World Bank. These models specifically relate net farm revenue or land price to temperature and precipitation, and include seasonal detail. The corresponding measures of change in agricultural productivity resulting from climate change are percent change in yield per hectare, in the crop models, and implied percent change in output per hectare, in the Ricardian models.

A key decision in such estimates is how much benefit to allow for "carbon fertilization." Recent

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open-air experiments have shown only about half as much yield gain as earlier laboratory experiments. My estimates allow for a weighted-average 15 percent yield increase from the doubling of carbon dioxide in the atmosphere from today's levels by the 2080s (to 735 parts per million).

My estimates take the average of the results obtained by applying the crop models and the Ricardian models to the detailed geographical estimates of climate change by the 2080s. Aggregate world agricultural productivity would decline by an estimated 16 percent from baseline levels, if carbon fertilization is omitted, and by 3 percent if it is included (Table 1). Both sets of estimates are probably on the optimistic side, because they do not take account of losses due to increased pests or increased incidence of extreme weather events (including floods and drought). The Ricardian estimates implicitly assume that more water will be available for irrigation whereas in some regions (notably Africa) greater water scarcity is likely.

Table 1 Impact of Global Warming on Agricultural Output Potential by 2080s (percent)

	Without carbon fertilization	With carbon fertilization
World		
Output-weighted	-15.9	-3.2
Median by country	-23.5	-12.1
Industrial countries	-6.3	7.7
Developing countries		
Output-weighted	-21.0	-9.1
Median	-25.8	-14.7
Africa	-27.5	-16.6
Asia	-19.3	-7.2
China	-7.2	6.8
India	-38.1	-28.8
Middle East/North Africa	-21.2	-9.4
Latin America	-24.3	-12.9

Figure 1 displays the estimated impacts by country for the case without carbon fertilization. Potentially severe losses are evident in Latin America, Africa, Australia, and the Southern regions of the United States. As indicated in Table 1, the developing countries are hit much harder than the industrial countries. India shows the largest potential losses, at about 30 percent even if carbon fertilization gains are included. The typical (median) loss among developing countries is 26 percent if carbon fertilization fails to materialize and 15 percent even if it does occur.

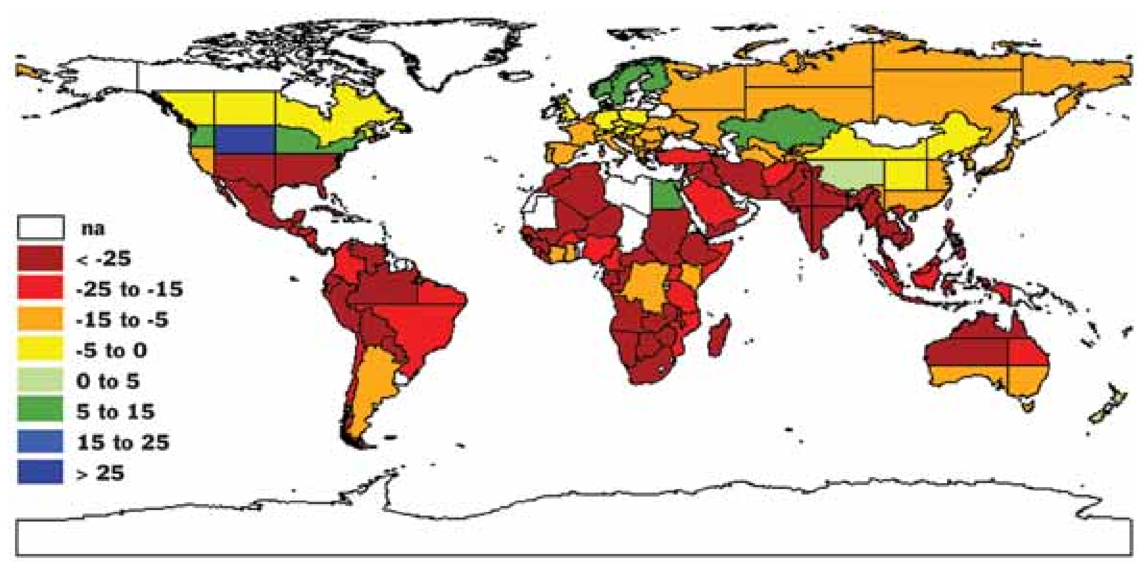
The most intriguing exception is China, where losses are a modest 7 percent without carbon fertilization and there are comparable gains if that effect is included. Within China, however, the regional distribution of losses is wide—as shown in Figure 1, losses could be as large as 15 percent in the South Central region in the case without carbon fertilization.

In contrast to the potentially deep losses in developing countries, average effects are more moderate in industrial countries, ranging from a decline in output potential of about 6 percent without carbon fertilization but an increase of about 8 percent with carbon fertilization. So global warming will disproportionately cause damages to agriculture in developing countries. This asymmetry is amplified by the fact that agriculture constitutes a much larger fraction of GDP in developing countries than in industrial countries.

The primary implication of these findings is that it would be a serious mistake to view agricultural effects of global warming as broadly benign. Some estimates, which use Ricardian models similar to those I applied, have suggested that by late in this century world agriculture could actually still be benefiting rather than experiencing losses from global warming. Close examination reveals that such estimates have tended to understate the extent of prospective warming and overstate the extent of carbon fertilization gains. It is also crucial to keep in mind that there is a lag of about thirty years between today's emissions and the time when the full extent of the resulting global warming arrives ("ocean thermal lag" associated with an initial period in which the deep ocean warms to reestablish equilibrium differential with surface temperatures). Indeed, my estimates are just a snapshot in time, and losses would be expected to grow more severe by early in the next century.

A natural question is whether these concerns are exaggerated because technological change will raise the baseline agricultural yields so much that the reduc-

Figure 1 Estimated impacts by country for the case without carbon fertilization



tions from global warming will not be a problem. My study finds, however, that technical change is no panacea. The green revolution has in fact been slowing down. Average yields per hectare rose at 2.8 percent annually in the 1960s and 1970s but only by 1.6 percent annually in the past two decades. When prospective world population growth and the rise in food demand from higher population and higher incomes are taken into account, there turns out to be a relatively close race between future baseline agricultural yields and world food demand. This race will be even tighter if, as seems likely, as much as a third of agricultural land is devoted to the production of biofuels rather than food by late in this century.

The most important developing country of all for global warming policy, China, is about neutrally affected overall.

The central policy implication of these findings is that international efforts to curb global warming are indeed warranted to avoid damage to world agriculture and especially significant damage in developing countries. Policymakers in the United States and Australia, the last two industrial-country holdouts against the Kyoto Protocol, seem on the verge of finally taking global warming seriously and moving toward some form of disincentives to carbon dioxide emissions. My new estimates on the stakes for global agriculture strengthen the case that it is high time they do so.

But the next phase of international action will also have to include serious efforts to deflect the otherwise rapidly rising future path of emissions in developing countries. Recent estimates indicate that over the next several decades the developing countries will contribute more to global carbon emissions than the industrial countries. Already China's emissions exceed those of the European Union and they will soon exceed those of the United States. For its part, India faces sufficiently drastic prospects that it would seem strongly in its own interest to participate in international efforts to reduce emissions, and to exert peer pressure on China to do so as well. The future populations of the developing countries will be the greatest victims if their current leaders take the position that emissions should be allowed to rise freely in their own countries. ◆