Center for Global Development

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Global Warming and Agriculture: New Country Estimates Show Developing Countries Face Declines in Agricultural Productivity

By William R. Cline*

Thanks to the growing body of evidence about global warming, including the high-profile "Stern Review" and successive reports by the Intergovernmental Panel on Climate Change (IPCC), public pressure for a more climate-conscious government response is increasing. In the United States, several states are adopting measures to discourage carbon dioxide emissions, and the Supreme Court has ruled that carbon dioxide is a pollutant to be regulated by the Environmental Protection Agency. Internationally, the European Union has established a functioning system of trading in carbon emission permits. Under the U.N. Framework Convention on Climate Change, negotiations could begin later this year on the post-Kyoto regime after 2012.

But while there is growing recognition that global warming is a problem, little attention has been paid to the likely impact at the country level, especially in the developing world. This Brief, based on the new book, Global Warming and Agriculture: Impact Estimates by Country, discusses the stakes for world agriculture, with special attention to China, India, Brazil, and the poor countries of the tropical belt in Africa and Latin America. The study shows, with more detailed and systematic estimates than previously available, that the long-term effects on world agriculture will be substantially negative, and that developing countries will suffer first and worst. The implications are sobering for all concerned about global poverty and long-term economic development.

Effects of Warming on Agriculture: Developing Countries versus Industrialized Countries

Previous studies have disagreed on the extent of prospective agricultural damages from global warming. Some have suggested that a few degrees of warming will cause minimal damage to agriculture and could actually be beneficial—because temperatures would be warmer in currently cold climates and higher concentrations of carbon dioxide in the atmosphere could result in increased crop yields (a phenomenon know as *carbon fertilization*). But even optimistic studies have agreed that there are likely to be adverse effects in many developing countries.

The decline in agricultural output capacity from global warming is worse in developing countries because they tend to be located closer to the equator where temperatures are already close to or beyond thresholds at which further warming will reduce yields, rather than increase them. These countries also have the smallest capacity to adapt to such changes. And because agriculture is a larger percentage of the GDP in developing countries than industrial countries, a given percent loss in a developing country results in a much greater relative loss in income than in the industrial world.

This study, which uses agricultural impact models of two separate types—"Ricardian" statistical economic models and process-based agronomic crop models, combined with leading climate

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model projections—projects overall declines in total global agricultural productivity of between 3 and 16 percent, depending on the extent of carbon fertilization.

The difference between the impact of global warming on agricultural productivity in developing countries and rich countries is stark: developing countries will face a 9 to 21 percent decline overall, depending on whether carbon fertilization benefits materialize, while industrial countries will experience a 6 percent decline to an 8 percent *increase*. (The map on page four shows the impact without carbon fertilization; for a map with carbon fertilization, see page 75 in the book.)

Percent Declines in Agricultural Productivity by 2080, Percent

Country	With Carbon Fertilization	Without Carbon Fertilization
India	29	38
Algeria	26	36
Iran	18	29
Mexico	26	35
South Africa	23	33

By the 2080s, unabated global warming would cause serious declines in agricultural productivity in Africa, Latin America, and South Asia, even with substantial carbon fertilization.

In larger countries, national averages can mask dramatic regional differences that will cause wrenching internal adjustments:

- In the **United States**, which would see an 8 percent increase at the national level if carbon fertilization gains are included (but a 6 percent loss if not), there would be large regional losses in output, including an 18 percent reduction in the Southeast and a 25 percent reduction in the Southwest Plains even including carbon fertilization.
- In **China**, the South Central region could face losses of as much as 15 percent even though aggregate effects nationally would range from about −7 to +7 percent.
- **India** is especially at risk, facing agricultural output losses of nearly 30 percent even under the best scenario, with a decline of as much as 44 percent in the northeast if carbon fertilization does not materialize.

These estimates probably err on the optimistic side, because they do not take into account the effects of increased losses due to insect pests, more frequent extreme weather events such as severe droughts and floods, and the increased scarcity of water for irrigation.

Uncertainty About Carbon Fertilization

The estimates above represent the combined results of the two agricultural output models that are first calculated excluding one important and uncertain variable: carbon fertilization. In addition to driving global warming, an increase in the amount of atmospheric carbon dioxide can cause an increase in agricultural output for some major crops. So while global warming may suppress output in a given region because of the effects of higher temperatures or changes in precipitation, the increase in carbon dioxide can cause an offsetting rise in yields.

Some of the leading previous studies have overestimated the positive impact of carbon fertilization on future yields by using values derived from experiments conducted within the confines of laboratories. The most recent studies of carbon fertilization, conducted in open-air field experiments, are producing much less optimistic results. For example, in one such open-air study, at 550 parts per million (ppm) of CO_2, wheat yields only went up 13 percent, in contrast to 31 percent in lab studies. Likewise, soybean yields in the field only went up 14 percent, compared to 32 percent in lab studies.

Taking these newer, more realistic studies into account, this study adopts a 15 percent increase in yield as a more conservative estimate of carbon fertilization by the 2080s, a considerably smaller percentage than in some past studies. Because this effect is so uncertain, the study also presents estimates that exclude carbon fertilization completely. Table 1 shows the agricultural impact by major regions, with and without carbon fertilization. Even with the boost from carbon fertilization, Africa (a 17 percent decline in output potential) and Latin America (13 percent decline), and South Asia (29 percent decline in India and 20 percent in Pakistan) are the developing regions most vulnerable to global warming. Europe, North America, and China have net gains, but Australia faces major losses in output capacity.

Technological Change

Why can't technological changes raise yields more than global warming reduces them? It is indeed likely that because of ongoing technological advances, agricultural yields will be higher late in this century than they are today, even in the face of global warming. However, demand for agricultural production will also be much higher. Several factors make it unlikely that technological change will be a panacea for addressing concerns about the adverse impact of global warming.

- Population will continue to rise. Between now and 2085, agricultural production must roughly double just to keep up with population growth.
- The demand for food will increase with rising per capita incomes, and a dietary shift toward meat.
- Increases in yield have slowed down in the past 20 years, and might slow further in the next eight decades.
- As much as one-third or more of agricultural land may be converted from food production to the production of energy crops to make ethanol.

Taken together, these considerations suggest that the balance between prospective supply and demand could be tight, allowing little room for damages imposed by global warming.

Conclusions

These findings of severe reductions in agricultural potential in many developing countries inject a new sense of urgency into worldwide efforts to reduce carbon emissions. Moreover, the findings cast serious doubt on the more optimistic previous studies estimating significant global aggregate gains in agricultural productivity.

The results have important implications for several major countries. Australia, which until recently has, with the United States, led the resistance against implementing the Koyoto Protocol, faces losses of 16 percent even with carbon fertilization. And as noted earlier, the United States, which might gain modestly overall, faces wrenching internal changes because of drastic losses in the Southeast and the Southwest Plains.

The findings also show that developing countries, which will be facing earlier and more severe losses, should be pushing hard for reductions in carbon dioxide emissions.

Moreover, the projections in this study stop at 2080, but without dramatic reductions in greenhouse gases global warming and the decline in agricultural productivity would both continue. Under the business-as-usual scenario, the levels of carbon dioxide in the atmosphere will continue to rise, reducing agricultural yields even further into the next century and beyond.

Table 1. Agricultural Impact by Major Regions: Developing and Industrial Countries

	Base Output $ billions 2003)	Population (millions)	Change in Agricultural Potential (percent)	
			without CF	with CF
Developing Countries	838	5,202	−19.7	−7.7
Excluding Europe	745	4,807	−21.0	−9.1
Africa	73	660	−27.5	−16.6
Nigeria	15	136	−18.5	−6.3
South Africa	6	46	−33.4	−23.4
Asia	500	3,362	−19.3	−7.2
China	213	1,288	−7.2	6.8
India	132	1,064	−38.1	−28.8
Indonesia	35	215	−17.9	−5.6
Middle East North Africa	61	280	−21.2	−9.4
Algeria	7	32	−36.0	−26.4
Egypt	13	68	11.3	28.0
Iran	15	66	−28.9	−18.2
Western Hemisphere	111	506	−24.3	−12.9
Argentina	14	37	−11.1	2.2
Brazil	30	177	−16.9	−4.4
Mexico	25	102	−35.4	−25.7
Europe	93	395	−9.4	4.1
Poland	5	38	−4.7	9.5
Russia	22	143	−7.7	6.2
Turkey	27	71	−16.2	−3.6
Industrial Countries	338	846	−6.3	7.7
Australia	13	20	−26.6	−15.6
Canada	17	32	−2.2	12.5
Germany	17	83	−2.9	11.7
United Kingdom	13	59	−3.9	10.5
United States	99	291	−5.9	8.2
World	1,176	6,049	−15.9	−3.2
Population-weighted:			−18.2	−6.0

CF: Carbon Fertilization

MORE ABOUT THIS STUDY

This study's findings are based on a combination of results generated from the best available climate models and the two major types of agricultural impact models. The methodology grows out of previous studies by other authors, with a careful dissection of assumptions in some of these studies, which might have led to overly optimistic results. Although the underlying models show a range of results, the strategy of this study is to develop what can be called a consensus estimate, both for the climate changes and for the resulting agricultural impacts. The alternative of enumerating a wide range of results has in the past contributed to a paralysis of action by invoking the wide range of uncertainty. Moreover, it turns out that the country-impact profiles estimated in this study show considerably greater similarity among the alternative climate models, and between the two families of agricultural impact models, than might have been expected in view of the general public impression of wide ranges of uncertainty for climate change estimates.

Geographical Detail

The book contains tables with estimates for temperature, precipitation, and changes in potential agricultural output for 68 individual countries, 10 regions (containing a total of 39 more countries), and subzones for the seven largest countries (China, India, United States, Canada, Australia, Russia, and Brazil), for a total of 116 specific geographical areas.

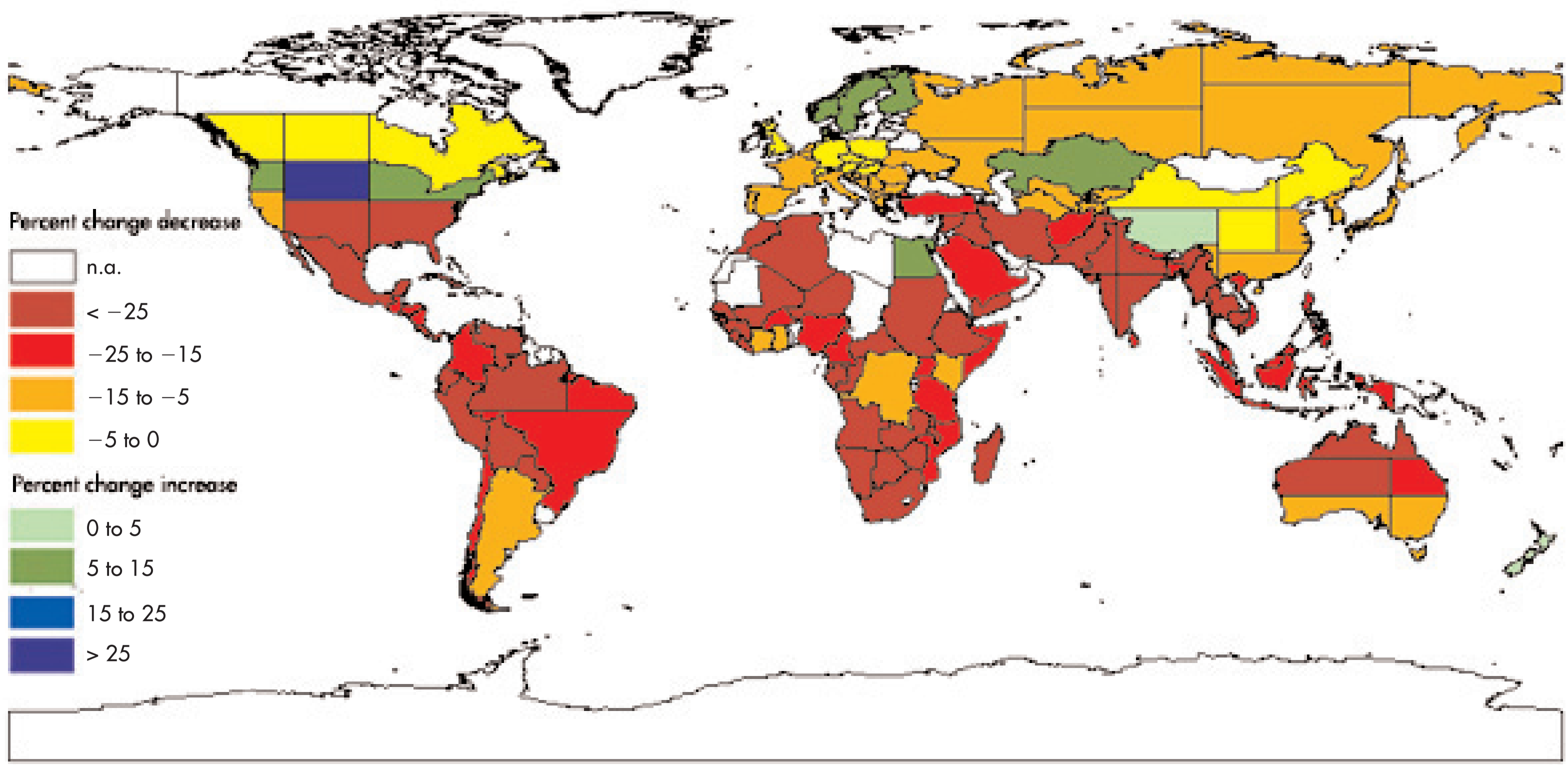
A Consensus Climate Projection

This study begins with climate projections based on IPCC models and then applies the expected changes to leading agricultural impact models that relate yields or net farm income to temperature and precipitation, in some cases with seasonal detail. For the climate component, temperature and precipitation estimates are based on the averaged results from six global climate models (more formally known as general circulation models, or GCMs) for each of the 116 geographic areas, producing a consensus climate projection for application to the agricultural impact models. This study assumes "business-as-usual" (BAU) for the path of greenhouse gas emissions from now until late in this century (the period 2070-2099, or "the 2080s"). The BAU scenario assumes that there are no major global initiatives to reduce carbon dioxide emissions, to provide a benchmark for the stakes involved if no action is taken.

A Synthesis of Agricultural Output Models

The study combines the results from two types of agricultural output models, Ricardian models and crop models, using the temperature and precipitation figures from the consensus climate projections. The study takes the average of the Ricardian and crop-model estimates as the best estimate of the impact on agricultural output for a given country, region, or subzone.

Impact on Agricultural Productivity Without Carbon Fertilization (percent)



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