In Short ■ by Thomas E. Drennen and Harry M. Kaiser

Global warming and agriculture: The basics

Scientists predict that continued emissions of carbon dioxide (CO_2) and other greenhouse gases will increase global temperature by 1.5° to 4.5°C (3° to 8°F) over the next 100 years. Several reports indicate that the earth's temperature increased 0.5°C during this century, with seven of the warmest years on record occurring in the past ten years.

Global climate change will affect agriculture in two ways. First, increasing temperatures and shifting precipitation patterns will directly affect agricultural productivity and management practices. Second, international actions may require changes in agricultural practices which contribute to climate change.

Impact of climate change on agriculture: some important uncertainties

Predicted changes in temperature and precipitation will affect agriculture. Some studies suggest that crop production in the northern regions of Canada, Europe, and the former Soviet Union may benefit from climate change. Other countries, particularly those in the northern middle latitudes including the United States, Western Europe, and most of Canada, could experience decreased agricultural productivity. China and Japan, however, may benefit because their agriculture lies primarily in coastal regions and will probably not experience interior continental drying

Table 1. Predicted change in temperature and precipitation due to atmospheric doubling of CO_2, three climate models for U.S. regions

	Change in Annual Surface Temp (°C)			Change in Precipitation (%)		
Region	GISS	GFDL	UKMO	GISS	GFDL	UKMO
Pacific	4.4	4.0	6.7	15	6	16
Mountain	4.9	4.5	6.0	14	-3	24
Mountain Plains	4.8	4.3	6.8	-1	13	13
Southern Plains	4.6	4.2	6.7	-9	6	-18
Lake States	4.9	4.4	8.8	7	34	9
Corn Belt	4.8	4.7	8.3	6	11	1
Delta States	3.4	3.7	6.2	-2	17	3
Northeast	4.6	4.9	8.7	-5	-8	16
Appalachian	4.6	4.1	7.1	9	1	6
Southeast	3.6	3.8	6.8	6	5	-7
U. S. Average	4.5	4.3	7.2	4	8	6

GISS = Goddard Institute for Space Studies climate model.
GFDL = Geophysical Fluid Dynamics Laboratory climate model.
UKMO = United Kingdom Meteorological Office climate model.
Source: Rosenzweig, C. and A. Iglesias. eds. 1993. *Implications of Climate Change for International Agriculture: Crop Modeling Study.* Washington, DC: U.S. Environmental Protection Agency, (in press).

Sources of Greenhouse Gases

Carbon Dioxide

Future emissions of CO_2 depend on the consumption of fossil fuels and levels of deforestation. Fossil fuels emit 6.0±0.5 gigatons (same as 1 billion metric tons) carbon per year. Estimates of CO_2 released as a result of land use changes (mainly deforestation) are 1.6±1.0 gigatons carbon per year. Of these total emissions of 6.1–9.1 gigatons carbon, approximately 3.2–3.6 gigatons carbon remain in the atmosphere. The oceans and the biosphere absorb the remainder.

Methane

The sources and sinks for methane are even less well-quantified than CO_2. Sources include natural wetlands and bogs, rice paddies, intestinal fermentation occurring in animals; animal wastes; biomass burning, and coal mining; and the drilling, venting, and transmission of natural gas. Estimates of total anthropogenic (human related) emissions range from 240 to 570 million metric tons. The atmospheric content of CH_4 increases annually at 32 million metric tons. The remainder breaks down in the atmosphere. Methane is 9 to 63 times more effective (per unit) as a greenhouse gas than CO_2.

Nitrous Oxide

Even greater uncertainty exists for this greenhouse gas. Atmospheric concentrations increase annually by 3.0–4.5 million metric tons. The main source appears to be from the cultivation of soils and denitrification of soils. Other sources include biomass and fossil fuel combustion. The main sink is through photochemical decomposition in the stratosphere. Nitrous oxide is estimated to be 180 to 290 times more effective as a greenhouse gas than CO_2.

CFCs

This group of chemicals, widely used in aerosols, insulation, and as solvents are regulated under the 1987 Montreal Protocol because of their ability to damage the stratospheric ozone layer. As a result of this agreement, consumption of various CFCs has decreased worldwide by as much as 40 percent from 1986 levels. Unfortunately, many of the proposed substitutes for these chemicals, while ozone friendly, are also very strong greenhouse gases, 1,000s of times more potent than CO_2.

to accompany global warming. Developing countries will probably be more negatively affected than developed countries because they have fewer resources to adapt to climate change. The economic effects of climate change may be very different from the productivity impacts. Even under fairly sizable negative yield impacts, studies have shown that the interregional adjustments in the world market may cushion much of the adverse impact on economic welfare.

Predictions of global climate change, however, are quite uncertain because of the tremendous inaccuracy of the current climate models. These climate models assume atmospheric CO_2 doubles from pre-Industrial Revolution levels, in the mid 21st century. Table 1 shows the predicted change in temperature and precipitation for U.S. regions from three leading climate models. Model predictions vary sharply, especially in predicted change in precipitation. The discrepancies are due to differences in the modeling of clouds and oceans, as well as poor model resolution. For example, the models assign single variables for areas approximately the size of Colorado, thus overlooking the large variation in weather that can occur between mountainous and rangeland areas. Certainly one important research need is to improve climate models by improving model resolution (smaller grid sizes), and making refinements in the coupling of ocean and atmospheric modules.

We also have much to learn about CO_2 fertilization. Crop yields may *increase* because elevated atmospheric CO_2 increases net photosynthesis and reduces stomatal openings to improve water-use efficiency of plants. But we do not know how much CO_2 fertilization might increase yield. Some evidence from short-term laboratory experiments shows sizable increases in yield due to CO_2 fertilization. However, extrapolating laboratory experiments to actual field conditions may overstate the magnitude of CO_2 fertilization because field conditions are far less ideal than the laboratory environment, especially in input-scarce less developed countries.

Agriculture's contribution to global climate change

Agriculture will also affect the eventual magnitude of climate change. Various estimates place agriculture's contribution at between 15 and 33 percent of anthropogenic (human caused) greenhouse gas emissions worldwide. The remainder comes mainly from fossil fuel sources (see above). Differing definitions of what constitutes agricultural sources largely explains this wide estimate range. For example, most estimates attribute deforestation emissions to the agricultural sector. Since defor-

The Push to Prevent Global Warming

June 1992. *United Nations Conference on the Environment and Development (UNCED).* Leaders from 153 countries sign the *Framework Convention on Climate Change* which calls for the eventual stabilization of greenhouse gases in the atmosphere. In the short term, developed countries agreed to a voluntary pledge of returning greenhouse gas emissions to 1990 levels by the end of the decade. The agreement entered into force on March 21, 1994. The United States ratified the agreement in 1993.

April 1993. Earth Day. President Clinton announces his intention to commit the U.S. to hold aggregate U.S. emissions to 1990 levels.

October 1993. United States releases its Climate *Action Plan*, described as a blueprint to accomplish the Earth Day Pledge. The Plan contains fourty-three Initiatives, including two for agriculture. The AgStar program (EPA, USDA) will be expanded to achieve 50 percent of the total methane reductions profitably recoverable from animal wastes. Further, USDA and EPA will coordinate research efforts to improve overall ruminant productivity to reduce methane emissions. Possible options include: improved feed efficiency, increased nutritional content of feeds, and improved reproduction techniques.

estation accounts for 20 percent of all anthropogenic emissions, this overstates the true agricultural contribution.

Some overestimate agriculture's contribution to greenhouse gases because they overlook net carbon emissions. When a cow releases CH_4, she recycles carbon. Ignoring this recycling overstates the role of ruminant CH_4 by as much as 40 percent. Similarly, many rice paddies were once natural wetlands or swamps, which produce methane. The cultivation of rice on this land may not increase the net emissions of methane to the atmosphere.

Taking these other factors into account, we estimate that the agricultural contribution to climate change probably does not exceed 20 percent of total human-related emissions.

For more information

See H. M. Kaiser and T. E. Drennen, editors, *Agricultural Dimensions of Global Climate Change.* St. Lucie Press, 1993.

Thomas E. Drennen is a policy analyst with Sandia National Laboratories, and a former research associate in the Department of Agricultural, Resource, and Managerial Economics at Cornell University. Harry M. Kaiser is an associate professor in the Department of Agricultural, Resource, and Managerial Economics at Cornell University.