Resources & Environment

Global Climate Change: Could U.S. Agriculture Adapt?

The extent of potential climate change and its impact on farm productivity has been the subject of concern and investigation by economists as well as scientists since the late 1980's. An increase in concentrations of trace gases in the atmosphere has alarmed some scientists because these gases trap heat in the atmosphere (the "greenhouse" effect), affecting patterns of temperature and precipitation around the world.

These gases, whose concentrations are being increased by human activities, include carbon dioxide (CO_2), a by-product of fossil fuel combustion, forest clearing, and the decomposition of organic matter; methane, a by-product of cattle and rice production, and a gas released from landfills; and nitrous oxide, released from soils, particularly where nitrogen fertilizer is applied, and as a by-product of vehicle emissions and industrial activity.

The potential for climate change poses a serious challenge for world agriculture. How climate change will affect agriculture's ability to feed a growing world population is of critical importance.

Scientific uncertainty persists about the nature and rate of climate change. But an international panel of experts under the auspices of the U.N. has concluded that human activities are discernibly influencing the climate system.

A collection of recent research efforts at the farm, national, and global levels finds that while climate change can have impacts on the agricultural sector, there is considerably more sectoral flexibility and adaptation potential for U.S. agriculture than was found in *earlier analyses*. Negative effects of climate change on agriculture found in earlier studies were overestimated because they did not account for economic adjustments and adaptation, nor did they consider the broader economic and environmental implications of social changes that are likely to occur in the extended time frame of climate change.

Many scientists anticipate a doubling of the current concentration of carbon dioxide over a period of 80 to 100 years, if no emissions control measures are taken. This extended time scale will provide the opportunity for farms and other components of the agricultural system (e.g., input suppliers, water managers, food processing firms, and consumers) to take steps to adapt. Over the same period, changes in income and population, and in technology and technological innovation, will also be proceeding at different rates in different locations around the globe.

Although *recent studies* suggest that the U.S. agricultural system has significant potential to adjust to global climate change, the required adjustments could be quite disruptive to individual communities, or even larger agricultural regions. Switching from one crop to another might occur, or a local economy might gradually move from an agricultural-based to a service- or industrial-based economy.

Economic disruptions from potential climate change are likely to be more severe in poor countries where agriculture makes up a larger share of gross domestic product. These countries sometimes have fewer adaptation alternatives available to them, are often located in hotter, drier climates, and may have difficulties making farm- and regional-level adjustments. Global changes in production could affect U.S. agriculture through impacts on world commodity prices and the demand for U.S. exports. Foreign food aid requirements could also be affected.

Recent Studies Stress Role Of Adaptation

USDA's Economic Research Service (ERS) has evaluated the outcomes of earlier and recent studies of the effects of global climate change on agriculture. Estimating the economic impacts of climate change requires evaluation of many complex interactions. These considerations include trade, levels of research funding, technological options for adaptation, changes in crop yields and livestock productivity, economic and population growth, and changing commodity prices. When the results of earlier studies are compared with more recent, flexible modeling efforts, significant differences in findings emerge.

Earlier studies have highlighted potential negative impacts on agriculture from climate change. Farm-level declines in yield in Iowa and Nebraska for dryland maize, soybeans, and winter wheat have been estimated in previous work at between -76 and- 4 percent by the time atmospheric carbon dioxide (CO_2) doubles in 80 to 100 years. Recent studies that allow for a greater range of adaptation show that individual farm yields could increase or decrease (within a range of -24 percent to 24 percent) under identical climate scenarios and over the same time period. Both sets of yield results exclude the CO_2 fertilization effect—the stimulative effect that higher atmospheric concentrations of CO_2 may have on plant growth—to facilitate comparisons.

Yield results in *earlier work* assumed that farmers continue to plant the regional cultivars being planted now, implying that farmers would be unable to detect changing climate conditions even over a period of 50 to 100 years. Recent studies which give more optimistic results allow for adaptation alternatives—including planting later maturing cultivars that permit farmers to take advantage of longer growing seasons, earlier planting dates resulting from climate change, and changes in other field operations. In the recent studies, farmers select specific practices to maximize profits given their expectations about future climate.

To make the results as comparable as possible between the earlier and recent studies, ERS used the same locations (Des Moines and North Platte) and the same climate scenarios. Slight differences in soil types, and the generations of models capturing crop growth in the studies, explain very little of the differences between the results.

For the U.S. as a whole, *recent studies* that assume greater adaptation than earlier work, but no CO_2 fertilization effect, show impacts on the general economy of between -\$11.1 and \$33.1 billion annually. The U.S. agricultural production sector alone experiences impacts of -\$5.8 to \$33.1 billion annually. Producers can gain economically even if productivity falls due to climate change, if world prices for agricultural commodities rise sufficiently.

Recent studies of the U.S. are more comprehensive because their methods incorporate a wider set of adaptations and allow for interactions with markets outside of U.S. agriculture. These studies include data from all agricultural areas, so the set of adaptations available to farmers includes virtually anything currently done in U.S. agriculture.

In one of the recent studies (undertaken by ERS), the economic model used to estimate the effects of global climate change also incorporates the full set of interactions with nonagricultural sectors and other global regions. At the global level, where international trade allows disruptions in one area of the world to be compensated by improvements in another, world gross domestic product could increase or decrease by one-tenth of 1 percent (a range of \$24.5 to \$25.2 billion) with adaptation and no CO_2 fertilization effect, by the time atmospheric CO_2 doubles. Effects on individual regions can be larger than the net global effect because some regions lose while others gain.

The CO_2 fertilization effect, which has been largely left out of the analysis to facilitate comparisons between different studies, could be an important factor. While there remains scientific controversy concerning this effect, one study estimated CO_2 fertilization to add \$115 to \$190 billion to global agricultural income over the same time period as the other results.

There remain concerns about whether the full CO_2 fertilization effect will be realized. These include whether the fertilization effect continues over succeeding generations of plants; the differential impact on field crop species; and offsetting stimulative effects on competing weeds.

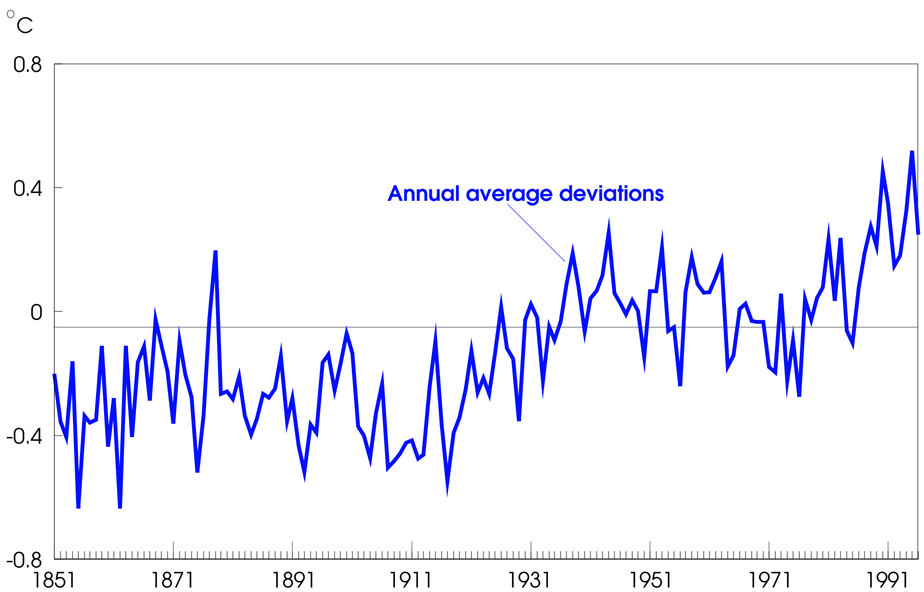
Other potentially negative offsetting effects could be caused by other greenhouse gases. In addition, the results compare only two points in time—the present, and 80-100 years in the future (the benchmark for such studies)—and do not consider adjustment costs incurred in between. Climate variability and storm intensity, and the incidence and distribution of agricultural pests, may also change. These effects have not yet been factored into earlier and recent studies.

Global & Regional Competition

Agriculture must compete with other sectors for land, water, and investments of time and money. If, for example, conditions generally become more arid, competition among agricultural, urban, and industrial users of water would increase. Similarly, shifting of agricultural production to new areas could lead to conversion of grazing, pasture, or forest land to intensive cropland. If such conversions occur, it could contribute to loss of forests and natural ecosystems even as climate change is simultaneously disrupting them.

International trade effects filter down to the local level. The economic impact of climate change on the U.S. farm sector

Global Temperature Shows Apparent Pattern of Increase



Termperature deviations from 1961-90 average. Derived from monthly average global surface air temperatures.
Source: Phil Jones, *Climate Change 1995*, U.N. Intergovernmental Panel on Climate Change, second assessment report.
Economic Research Service, USDA

International Agreement to Limit Greenhouse Gases

The U.N. Framework Convention on Climate Change (FCCC), signed at the U.N. Conference on Environment and Development held in Rio de Janeiro in 1992, provides the broad outline for negotiating what countries will do to limit greenhouse gas (GHG) emissions. The Convention became effective in 1994 when 54 countries, including the U.S., ratified the agreement.

The U.S. position in these negotiations is to seek a framework designed to ensure that commitments to reduce GHG's are realistic and credible while preserving maximum flexibility to implement those commitments. The U.S. has been concerned that the existing framework of nonbinding emissions reduction goals is not working.

Agriculture is both a source and a sink for GHG's. Under the existing U.S. Global Change Action Plan, agricultural emissions are targeted for reductions. Further international commitment would likely affect U.S. agriculture.

Agricultural production is the source of about 5 percent of net annual U.S. GHG emissions on a carbon-equivalent basis (gases contributing more to the problem are given greater weights). In the U.S., forest growth and land use changes currently offset about 8 percent of total annual GHG emissions on a carbon-equivalent basis, acting as a so-called "sink" for trace gases. These sinks could be further enhanced through changed soil and forest management , thereby offsetting more industrial GHG emissions.

Some studies indicate that, technically, agricultural and forest carbon sinks could offset a majority of total U.S. GHG emissions. But the costs and feasibility of significantly enhancing these "sinks" has not been extensively investigated.

and consumers depends not only on how production potential is affected within the U.S., but also on how changes around the world affect export supplies and import demands of current and potential global trading partners.

While negative effects of climate change on agriculture have been largely overestimated by earlier studies that made weak assumptions—or none—about farmer adaptation, the recent studies, where results are more positive, have uncovered new concerns. Even though world aggregate production of major commodities might remain unchanged, the fact that this could be made possible by losses in agricultural potential from some regions being offset by gains in others, implies that distributional issues are paramount. In particular, some recent work has shown that the countries that are less able to absorb agricultural disruption might be exposed to the most negative effects.

Poor countries are most vulnerable to climate change because of the importance of agriculture in their gross domestic product; their location in hotter, drier climates; and difficulties in making farm- and regional-level adjustments. Moreover, climate change threatens to increase the incidence of hunger, malnutrition, and associated problems, which are concentrated in the developing world.

However, to the extent that these problems are due to low income rather than constraints on agricultural supply, they may be much less severe by the middle of the next century, even under modest scenarios for real income growth. The potential exception is Sub-Saharan Africa, where poor incentives for farmers, low agricultural productivity growth, slow income growth, and continued high population growth rates may compound the problems associated with food shortages.

Other Uncertainties Remain

For a number of reasons, results from studies of potential effects of climate change on agriculture must be qualified by an acknowledgment of some uncertainty. Government policies and programs ranging from crop insurance and disaster assistance to acreage reduction programs, tariffs and quotas, and the level of agricultural research, will affect the farm sector's response to climate change by affecting the economic incentives for farmers (and others) to adapt, and the technological options with which they can adapt. Despite past successes of agricultural and related research, public resources for agricultural research are becoming increasingly scarce worldwide.

In the U.S., attempts to tighten the Federal budget are having national implications for available real Federal funds. Many state governments have also cut real funds available for public agricultural research. The European Union is dramatically revising its plans for public agricultural research, with significant reductions in real resources. The international agricultural research centers have been hit by a large reduction in real resources as the governments of the developed countries have tightened their budgets.

Another area of uncertainty concerns a number of climate factors that are important for agriculture. Localized changes may be more rapid than the global average because geographic patterns can change at a different pace than the global mean. Changes in regular storm tracks could, over a few years, lead to greatly reduced rainfall in one area and increased rainfall in a new area.

Gradual change spread over several decades would allow for more opportunities for adaptation. But there is also no reason to believe that daily, monthly, and seasonal patterns of temperature and precipitation will remain unaffected. Recent history shows an upward trend in nighttime low temperatures in the Northern Hemisphere, but little or no change in daytime high temperatures. Heavy rain and high winds damage crops and cause soil erosion. Some scientific findings suggest that rainfall could become more intense with warmer temperatures.

One way to help the agricultural sector adapt to increased risk is to improve the information it receives. The following are a number of such incremental risks from a changing climate that may affect farmers and farm markets.

- *Extreme event risks*. Weather and climate are variable from day to day and season to season. Extreme weather events are the result of this variability. With an increase in average temperature or a change in mean precipitation, there could tend to be more days of extreme heat, heavy precipitation, or extended periods of drought. The variability of weather may also change, but the scientific evidence for how it might change is limited. If variability increases even as the mean conditions are changing, the likelihood of extreme weather events could be higher.

- *Field-time availability risks*. More extreme precipitation events, both wet and dry, affect the timing of field operations. Extremely wet weather in the spring, as experienced by Midwestern farmers in 1995, delays planting, possibly causing corn farmers to switch to soybeans. Dry weather late in the season, besides allowing access to fields, also reduces crop drying costs.

- *Yield risks*. When temperature and precipitation are too high or low, crop yields suffer. For example, 1988 was so dry that 30 percent of the anticipated U.S. corn crop did not materialize. It is difficult to forecast such events, but decisions on when to employ adaptation alternatives can be supported by the best available information.

- *Technology adoption risks*. Farm-level adaptations often involve switching to technologies that may not be in widespread use. There is a risk to individual farmers that a technology or combination of technologies may not perform adequately. There is inertia in technological adoption because farmers require evidence that new approaches work, are cost-effective, and are worth a fixed-cost capital investment that ties up money that will not be available for investments in the next new technology. Incentive programs may need to be developed in the future to promote the adoption of new climate-sensitive technologies.

- *Interactions between risk factors*. All of these risks are interrelated. Increased climate variability, for example, affects field-time availability, which in turn influences yield.

Climate scenarios produced by the General Circulation Models that were used in all of the referenced studies represent climates under a hypothetically doubled level of CO_2. They do not include a number of factors which will also affect climate over the next several decades. These include natural trends in climate and other factors such as sulfur emissions which have a cooling effect. The CO_2 warming effect is eventually expected to be the strongest factor affecting climate change, but over the next two decades other effects may be of equal magnitude.

Also, the climate scenarios do not include regional changes that could affect climate, such as wide-scale irrigation, deforestation, dust from tillage, and urbanization, all of which affect local temperature, precipitation, and insolation, or the amount of solar energy reaching the ground. While the combination of these effects may not have a significant effect on the global change in mean temperature or precipitation, they could make a substantial difference to local areas when combined with longrun climate change.

In the U.S., farmers, input suppliers, water managers, food processors and consumers are influenced by and respond to markets and broad expectations about future conditions including climate. Some decisions, such as water projects and other infrastructure investments, require long-term planning. For shorter term planning decisions—those with an investment life of less than 5 years—expectations about long-term climate change are less important. More analysis of climate trends, improved short- to medium-term climate projections, and research on appropriate adaptive responses under different climates could improve the adaptive capability of agriculture.

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Agricultural Adaptation to Climate Change: Issues of Longrun Sustainability

A report from USDA's Economic Research Service

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