

Climate Issues Brief No. 4

Impacts of Climate Change on Agriculture

Pierre Crosson ♦ June 1997

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IMPACTS OF CLIMATE CHANGE ON AGRICULTURE

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INTRODUCTION

Broad scientific agreement now exists that continued accumulation of heat-trapping “greenhouse” gases in the atmosphere will eventually lead to changes in the global climate, and in the climates of regions around the world. The agreement is expressed in the 1996 report of the Intergovernmental Panel on Climate Change (IPCC), an international body of leading natural and social scientists sponsored by the United Nations Environment Programme and the World Meteorological Organization. According to the panel’s report, an increase in atmospheric concentrations of greenhouse gases equivalent to a doubling of carbon dioxide (CO₂) will force a rise in global average surface temperature of 1.0 to 3.5 degrees Celsius by 2100. Average precipitation also will rise as much 10 to 15 percent because a warmer atmosphere holds more water.

The general circulation models (GCMs) that the IPCC used to analyze climate change are in reasonably good agreement that with a doubling of atmospheric CO₂ the global average temperature will rise within the range of 1.0 to 3.5 degrees Celsius, as indicated above. The models also agree reasonably well that the northern latitudes will warm more than the tropics. With respect to all other regional changes, however, agreement among the models is poor. Because human activities and ecological systems are highly variable among regions, this lack of accord greatly complicates the task of estimating the impacts of the changes on activities of interest to humans.

Despite this limitation, much useful work has been done on estimating the potential impacts of different climate change scenarios. In this paper potential climate change impacts on agriculture are examined on both a global scale and with regard to the United States in particular. Even if the reader’s interest lies only in the impact on the United States, the global scale still must be considered. U.S. agriculture is inextricably entwined with agriculture worldwide. What might happen nationally cannot be understood without taking account of impacts elsewhere in the world.

GLOBAL IMPACTS

The IPCC report estimates climate change impacts on grain production at the global level and then zeros in on the estimated effect on the developed countries (DCs) of North America and Europe as well as on the less developed countries (LDCs) of Asia, Africa, and Latin America.

(Grain is often used as a proxy for all food because it accounts for over half of all food calories consumed in the world.) The sources of the IPCC estimates are the three different GCMs, reflecting four different scenarios for estimating climate change impact on grain production.

- **First scenario.** Disregards any adjustments that farmers might make to offset the impacts of climate change on grain production, and disregards the effects on production of an atmosphere richer in CO₂. (CO₂ is essential to plant growth, and much experimental work shows that higher concentrations of it in the atmosphere in fact stimulate such growth);
- **Second scenario.** Incorporates the CO₂ enriching effect on growth;
- **Third scenario.** Includes both the CO₂ enriching effect and the effect of modest adjustments that farmers could make using currently known practices, for example, shifting to a different variety of the same crop and changing the planting date by less than one month in response to a change in the length of the growing season;
- **Fourth scenario.** Includes the CO₂ effect on growth, the modest adjustments to farming just mentioned, as well as more ambitious adjustments, such as shifting to an entirely different crop, changing the planting date by more than one month, and using more irrigation.

Note: The farming adjustments considered in the IPCC scenarios apparently *did not include* developing entirely new crop varieties designed to be more productive under changed climate conditions. However, research done on the impacts of climate change in the midwestern United States indicates that such new technologies could potentially offset much of the negative effects of climate change on crop production. And, since the climate change contemplated is not expected to be fully realized until sometime in the second half of the next century, plenty of time is still available for researchers to develop the new technologies needed to make this most advanced type of adjustment (see further discussion of this adjustment in the account of impacts on U.S. agriculture, below).

The IPCC analyses of the four scenarios are summarized in Table 1. The range in each entry reflects differences in the results obtained with the various climate models. Notably, the CO₂ fertilization effect substantially reduces yield losses and may even lead to net increases in grain output in developed countries as a whole. Smaller but significant offsets are obtained by allowing for adaptive behavior by farmers. Notwithstanding these adjustments and offsets, however, climate change is indicated by the IPCC report to reduce grain yields in developing nations, underscoring the greater vulnerability of these countries.

The sharp difference in impact that climate change is expected to have on grain production in developed as opposed to less developed countries has two main causes. The first one might be called the “physical” factor. As noted above, the GCMs estimate that the high latitudes will warm more than the tropics. Most of the DCs are in the northern latitudes, and their agriculture would benefit from the longer growing seasons that a warmer climate would bring. Most LDCs, on the other hand, include much terrain in the tropics where the negative effects of a warmer climate would not be offset by other favorable trends.

The second reason might be called the “eco-structural” factor. The IPCC notes that, compared with the LDCs, the DCs have much greater economic resources that can be devoted to helping farmers adjust to climate change. In addition, the institutional structures of the DCs appear to be more efficient than those in the LDCs in mobilizing the resources needed to pursue specific social objectives, whether they be adjustments to climate change or anything else.

If the GCMs are right in predicting generally beneficial climate change in the northern latitudes, then the physical factor accounting for the difference in impacts on the DCs and the LDCs would seem to be pretty much fixed. But the effect of the eco-structural factor may be more malleable. In east and southeast Asia, and to a lesser extent in south Asia, agricultural performance over the last 10 to 15 years has been impressive. Farmers have adopted new, more productive technologies as they have become available and production, both per person and per hectare, has increased. This strong agricultural performance has been part of a generally impressive economic performance in the countries of those regions.

It is not clear why some Asian countries have been so much more successful than countries in Latin America, and especially in Africa. Their success does suggest, however, that the eco-structural weaknesses so common now among the LDCs are not fixed for all time. The Asian experience offers some promise that, given time and incentive to improve their material standard, farmers in other LDCs can and will seize the opportunities presented. This prospect provides some reason to hope that by the time that climate change begins to impinge negatively on LDCs, they will have developed a capacity to adjust to it well beyond what they could accomplish under present conditions. If so, the differences between the DCs and LDCs in terms of the effects of climate change on grain production could be much less than the 1996 IPCC report suggests.

Recent studies done at the U.S. Department of Agriculture (USDA) and by Cynthia Rosenzweig and Martin Parry generally support the findings of the 1996 IPCC report about the global impacts of climate change on agriculture. A 1995 USDA study, for example, indicates that—overall—the impacts would be small, taking into account adjustments in agriculture and other sectors of the economy made possible by wide trading opportunities among countries. Specifically, the study showed that, given these trading opportunities, gross world economic product in the face of climate change would be 0.2 less—or 0.1 percent more—than it would be in the absence of climate change. Allowing for trading opportunities and farm-level adjustments, including the ability of farmers to move land into and out of production depending on the economic effects of climate change, the study found that world cereal production would increase 0.2 to 1.2 percent. *These results did not include the positive production effects of CO₂ enrichment.*

Table 1. Estimated Percentage Grain Production Changes from Climate Change

Scenario	World	Developed Countries	Developing Countries (Asia, Africa, Latin America)
No offsetting effects considered	-11 to -20	-4 to -24	-14 to -16
Including CO ₂ fertilization effect	-1 to -8	-4 to +11	-9 to -11
Including CO ₂ fertilization and Modest farmer adaptation	0 to -5	+2 to +11	-9 to -13
Including CO ₂ fertilization and more ambitious farmer adaptation	-2 to +1	+4 to +14	-6 to -7

Source: 1996 IPCC Report.

Rosenzweig and Parry also estimated changes in cereal prices resulting from climate-induced changes in production. The direction of change is consistent with well-established knowledge about price-production relationships in agriculture: Prices are what economists call “inelastic,” that is, a given percentage change in production is associated with a significantly greater “opposite direction” percentage change in price. That is, a given percentage decline in production because of climate change would result in a greater percentage increase in prices, and vice versa for production increases.

U.S. IMPACTS

The 1995 USDA study mentioned above found that in the United States both crop and animal output would fall under the type of long-term climate change likely to occur in response to a doubling of atmospheric CO₂ (hereafter written 2XCO₂). The model used in this study took account of climate change impacts elsewhere in the world, and the consequent changes in U.S. trading opportunities in agricultural commodities. The crop production declines in the United States would be small, from 0.8 percent to 3.4 percent. Livestock production would fall between 0.5 percent and 1.3 percent.

These estimates *do not reflect the positive crop production effects of CO₂ enrichment*. They do reflect farm-level adjustments that farmers would find economical among the practices available in 1990, including shifting land into and out of production. They *do not, however, include all adjustments likely to be available by the time climate change impacts might become significant*, say around 2050. Additional adjustment possibilities almost surely will include those that agricultural research establishments would develop in response to emerging evidence that the climate is changing. With these new adjustment possibilities available to farmers, the impacts of climate change on U.S. crop and animal output would likely be less harmful or even positive. Such an outcome is indicated in a study by Robert Mendelsohn and colleagues and in a study done at Resources for the Future focusing on the four states of Missouri, Iowa, Nebraska, and Kansas (hence the MINK study). The RFF study is of particular interest in that the effects of climate change were calibrated to actual experience during the drought years of the 1930s, rather than to the results of GCMs.

POLICY ISSUES AND CAVEATS

In thinking about policy issues related to prospects for global agricultural development, especially in the LDCs (where, studies show, over 90 percent of the increase in global demands for food will occur over the next 30 or 40 years), the prospective impact of climate change is at most of secondary importance. Studies done to date show that the impact on the already struggling LDCs is likely to be negative, but not disastrous (according to the IPCC report production would be down only 6 to 8 percent after accounting for on-farm adjustments). Moreover, by the time climate change impacts become significant in the middle of the next century, LDCs should be in much better shape to deal with the impacts than they are now. This will be especially the case if the world trading system in agricultural commodities remains as robust as it presently is and if the global impacts of climate change on agriculture are small (or positive). I return to these caveats below.

In addition, the amount of time before climate change impacts occur is expected to be long relative to the time needed to develop technological and managerial responses. Many of the farm-level responses incorporated into the impact models described above are already known to farmers and suppliers of farm inputs. They could be adopted in a year or two. To develop entirely new technologies and practices better adapted to the changed climate, the elapsed time from beginning of research to the availability of results to farmers would be some 10 to 20 years. Thus, if significant impacts on agriculture are not likely to be felt for another 30 or 40 years, there is time to develop technological responses, *if investments in agricultural research do not lag*. Only development of large surface irrigation projects involves a time span comparable to that expected before the impacts of climate change on agriculture are felt. And most irrigation systems developed over the last decade or so operate by pumping groundwater. These systems require much less time to develop than surface systems.

Quite apart from the relatively long-term issue of climate change impact, many LDCs—especially in Africa but also to some extent in Latin America and parts of Asia—face immediate problems that are severe. These problems inhibit achievement of sustainable agricultural systems—

systems that can meet rising demands for food and other agricultural commodities at socially acceptable economic and environmental costs into the indefinite future. Natural resource degradation is serious in some parts of those countries, but recent studies indicate that, in general—and contrary to a widely held view—degradation of land and water resources is not a major threat to agricultural sustainability in the LDCs. The critical issue, rather, is whether in the immediate future and over the next several decades these countries can develop the capacity to increasingly expand the knowledge base needed to achieve sustainable agricultural systems.

The needed knowledge is embodied in people, technology, and institutions. Over the last thirty years food output per person has increased 15 to 20 percent in the LDCs as a whole (but not in Africa). Farmers are better educated and trained, new technologies—those embodied in the Green Revolution being the outstanding examples—have been developed and widely adopted by farmers, and institutional performance has improved as people have become more aware of the importance of markets and secure property rights in providing farmers the incentives they need to adopt new technology.

Now, however, evidence suggests that the systems that generated the powerful increases in the three kinds of knowledge are in jeopardy. In Africa, for example, where supplies of the three kinds of knowledge are in particularly short supply, investments in rural education, after advancing smartly in the 1960s and 1970s, declined sharply in the 1980s and have not yet shown much evidence of a turn-around. Spending on agricultural research in that region also has declined in recent years, precisely the period when it should have been increasing robustly if Africa is to achieve sustainable agricultural systems. According to studies done at the International Food Policy Research Institute, agricultural research spending elsewhere in the developing world also is either declining in absolute amount, or the rates of increase in such spending are down sharply.

These threats to the knowledge base needed for continued progress in LDC agriculture are immediate and of major importance. If the threats can be overcome, LDC agriculture will prosper and, by the time the climate may change significantly, those countries will be in a reasonably strong position to deal with its consequences. If the threats are not overcome, the resulting economic, social, and political consequences over the next few decades will make the consequences of climate change pall in significance.

Implicit Assumptions

The assertion that, from a policy standpoint, the agricultural consequences of climate change on LDCs are relatively less important than other problems of agricultural development in those countries hinges on four so far implicit assumptions. One is that the GCMs used in climate change research give a reasonably accurate account of the changes that might occur, at least on global and continental scales. However, enormous uncertainty still surrounds most aspects of climate change, particularly its characteristics on subcontinental and smaller regional scales. It is on these scales that, as the saying goes, “the rubber hits the road,” that is, where we need to know in some detail how the climate might change. We do not now know this.

A second implicit assumption is that the climate will change in what climate researchers call a “linear” fashion. That is, it will evolve without major ups and downs from what it is today to whatever it will be at equilibrium with $2XCO_2$ warming sometime in the second half of the next century. The assumed gradualness of the process underlies the thought that society will have time to adjust to whatever climate change may bring. The assumption of linear change, however, may prove unfounded. Some evidence from the ancient climate record suggests that, occasionally, for unknown reasons, the world’s climate has changed in a rather short and chaotic fashion. If global warming produced such a response, the consequences for agriculture could be more severe. Even “linear” climate change could increase the frequency of extreme weather events, with more pronounced periods of drought and flooding. These possibilities are not picked up in the relatively benign scenarios of the IPCC and of the other researchers referred to above.

The conclusion that the impact of climate change on global and LDC agriculture will prove less important than other issues also assumes that the impacts will be limited to those resulting from $2XCO_2$ warming. But the focus on $2XCO_2$ is simply an analytical convenience adopted by climate researchers. Nowhere is it written that the atmospheric accumulation of CO_2 and other greenhouse gases must stop at an equivalent of $2XCO_2$. Unless measures are taken to eventually bring the emissions of these gases to a level where they can be absorbed by the oceans and the terrestrial biosphere, they will continue to accumulate in the atmosphere and continue to warm the earth beyond what might occur with $2XCO_2$. In this case, all the studies of climate change consequence reviewed above likely would prove to be irrelevant.

Finally, the conclusion that the climate change impact on LDC agriculture is of relatively small importance assumes that LDCs will continue to make good economic progress, and that the world trading system in agricultural products will be no less robust than it is now. Both of these assumptions underlie the argument that, by the time climate change begins to pose a threat to their agriculture, LDCs will be in much better shape than now to deal with the threat. If either of the assumptions fails, then the conclusion probably would no longer be warranted.

These caveats must be kept “up front” in thinking about climate change and its consequences for global and LDC agriculture. Given that, we nonetheless must go with what we think we presently know about these consequences. What we think we know supports the conclusion that DC agriculture may in fact benefit from the kind of climate change likely to result from $2XCO_2$ warming. And, although climate change is likely to damage LDC agriculture, the LDCs face other immediate threats that far outweigh the distant ones that climate change may bring.

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FURTHER READING

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About RFF

Resources for the Future (RFF) is an independent, nonprofit research organization that aims to help people make better decisions about the conservation and use of their natural resources and the environment. For the past 45 years, researchers at RFF have conducted environmental economics research and policy analysis involving such issues as forests, water, energy, minerals, transportation, sustainable development, and air pollution. They also have examined, from a variety of perspectives, such topics as government regulation, risk, ecosystems and biodiversity, climate, hazardous waste management, technology, and outer space.

While many RFF staff members are economists by training, other researchers hold advanced degrees in ecology, city and regional planning, engineering, American government, and public policy and management. RFF neither lobbies nor takes positions on specific legislative or regulatory proposals. Its operating budget is derived in approximately equal amounts from three sources: investment income from a reserve fund; government grants; and contributions from corporations, foundations, and individuals (corporate support cannot be earmarked for specific research projects). Some 45 percent of RFF's total funding is unrestricted.

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About RFF's Climate Issues Briefs

As decisionmakers prepare for domestic policy debates and the ongoing international negotiations under the Framework Convention on Climate Change, RFF's climate issues briefs provide topical, timely, and non-technical information and analysis. They are intended to integrate the various aspects of climate change with critical reviews of existing literature and original research at RFF on climate policy, energy markets, water and forest resource management, technological change, air pollution, and sustainable development.

Forthcoming briefs will examine issues related to domestic emissions trading programs; the scheduling of emissions reductions over time; the potential for technical innovation to substantially lower the cost of limiting greenhouse gases; and different modeling approaches for assessing the economic costs of limiting emissions of greenhouse gases.

About RFF's Climate Economics and Policy Program

As international debate intensifies over possible agreements to limit emissions of greenhouse gases, Resources for the Future (RFF) launched its Climate Economics and Policy Program in October 1996 to increase understanding and knowledge of the complex issues that must be addressed to design appropriate domestic and international policies that are effective, reliable, and cost-efficient. The program responds to both the long-term debate about climate change, and the specific debates surrounding the negotiations being carried out under the United Nations Framework Convention on Climate Change.

The publication of the Second Assessment Report of the Intergovernmental Panel on Climate Change signaled the beginning of a broader agenda of research and debate on global climate change. While there is still scientific uncertainty about the magnitude of climate change risks, the world's policy makers are now shifting more of their attention to debating appropriate policy responses.

RFF brings a well recognized and respected reputation for objectivity to this debate. The Climate Economics and Policy Program integrates the many different aspects of climate change with ongoing basic and applied research at RFF involving energy markets, water and forest resource management, air pollution, environmental regulation, and sustainable development.

PROGRAM AREAS. Drawing on RFF's strengths in environmental and natural resource assessment, economic analysis, and policy design, the climate program focuses on five main areas:

- Economic and environmental consequences of climate change and policies to deal with climate change.
- Domestic and international policy design issues.
- Interactions between climate change and other policies.
- Equity, efficiency, and other criteria used in decisionmaking.
- Development of analytical tools.

PROGRAM OUTPUTS. RFF's climate program includes original basic and applied research, policy analysis, and educational outreach.

Research. Integrating basic and applied research on the economic implications of global climate change with ecological, engineering, scientific, environmental health, geographical, international, and other considerations, an initial set of research projects underway at RFF include:

- Bringing Uncertainty into the Equation When Calculating Climate Change Risks
- Discounting in Intergenerational Decisionmaking (workshop)
- Economic Analysis of Greenhouse Gas Emissions Trading
- Effective Environmental Policy in the Presence of Distorting Taxes
- Electricity Restructuring and the Costs of Controlling CO₂
- Environmental Consequences of Tax System Reform
- Impacts of Climate Change Mitigation on Other Environmental Problems
- Importance of Technical Change in the Economics of Carbon Policy (workshop)
- International Cooperation for Effective and Economic Greenhouse Gas Limitation
- Vulnerability of Low-Income Households to the Hydrologic Effects of Climate Change

Policy analysis. As a response to questions arising in the ongoing international negotiations, RFF will issue a series of short papers on a variety of issues related to policy in 1997. These studies will be based on original research combined with critical reviews of existing literature. Potential questions to be addressed include:

- How should the climate problem be thought about in general?
- How might a domestic emissions trading program be established?
- How does the performance of revenue-raising and non-revenue-raising policy instruments compare?
- How should emissions reductions be scheduled over time?
- What is the potential for technical innovation to substantially lower the cost of greenhouse gas limitations, and what government policies can tap that potential?
- What are the strengths and weaknesses of different modeling approaches for assessing the economic costs of greenhouse gas limitations?

Educational outreach. RFF regularly shares its climate change findings with members of the academic, business and environmental communities, and representatives of local, national and international governments by publishing and disseminating discussion papers and convening educational forums on selected topics. To support a well-informed public, RFF provides regular reports of its climate change activities to the news media, posts program updates and activities on RFF's internet home page (<http://www.rff.org>), and will provide educational materials for lay audiences on the economics of climate change.

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Looking for an honest broker for climate change policy?

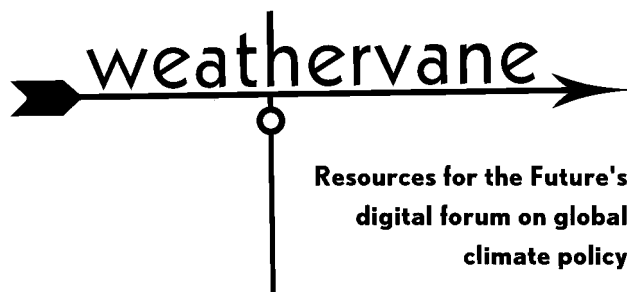
In light of the continuing international negotiations over climate change, Resources for the Future (RFF) publishes *Weathervane*, an internet forum dedicated to climate change policy. Just as a traditional weathervane tracks the direction of the wind, *Weathervane* has been tracking developments in climate change policy, both internationally and within the United States, since July 1997.

Our editorial aim is to present balanced and objective information, with no one perspective or viewpoint dominating our analysis and reporting. Now with an eye on the Fourth Conference of Parties, to be held in Buenos Aires, Argentina in November 1998, and the stakes potentially enormous on all sides of this complicated issue, *Weathervane* continues to provide a neutral forum for careful analysis to complement the political calculations that so often drive decisions.



Regular site features include: *Perspectives on Policy*, an opinion forum for invited players in the climate policy debate. It gives experts from every corner — business, government, environmental groups, and academia — an opportunity to weigh in with their opinions on a selected topic; *By The Numbers*, a regular column by RFF's Raymond Kopp to help decode and demystify energy and environmental data and create a better understanding of

the link between economic data and policy formulation; *Enroute to Buenos Aires*, which tracks developments in global climate change policy and players in the debate; *Research Spotlight*, which reports new climate findings and projects; and *Sounding Off*, an open forum for site visitors to voice their opinions on a variety of topics related to climate change.



**Resources for the Future's
digital forum on global
climate policy**

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