Adaptation

A wide variety of adaptive actions may be taken to lessen or overcome adverse effects of climate change on agriculture. At the level of farms, adjustments may include the introduction of later- maturing crop varieties or species, switching cropping sequences, sowing earlier, adjusting timing of field operations, conserving soil moisture through appropriate tillage methods, and improving irrigation efficiency. Some options such as switching crop varieties may be inexpensive while others, such as introducing irrigation (especially high-efficiency, water-conserving technologies), involve major investments. Economic adjustments include shifts in regional production centers and adjustments of capital, labor, and land allocations. For example, trade adjustments should help to shift commodity production to regions where comparative advantage improves; in areas where comparative advantage declines, labor and capital may move out of agriculture into more productive sectors. Studies combining biophysical and economic impacts show that, in general, market adjustments can indeed moderate the impacts of reduced yields.

A major adaptive response will be the breeding of heat- and drought-resistant crop varieties by utilizing genetic resources that may be better adapted to new climatic and atmospheric conditions. Collections of such genetic resources are maintained in germ-plasm banks; these may be screened to find sources of resistance to changing diseases and insects, as well as tolerances to heat and water stress and better compatibility to new agricultural technologies. Crop varieties with a higher *harvest index* (the fraction of total plant matter that is marketable) will help to keep irrigated production efficient under conditions of reduced water supplies or enhanced demands. Genetic manipulation may also help to exploit the beneficial effects of CO_2 enhancement on crop growth and water use.

Recent studies by the National Research Council and other organizations have emphasized the ability of U.S. farming to adapt to changing conditions, since in the past technological improvements have indeed been developed and put into use when needed. The U.S. has substantial agricultural research capabilities and a wide range of adaptation options is currently available to farmers in this country. Hence, insofar as the U.S. is concerned, prospects for agricultural adaptation to climate change appear favorable, assuming water is available. Considerable investments may be needed, however, to utilize soil and water resources more efficiently in a changed climate. Other countries, particularly in the tropics and semi-tropics, are not so well provisioned with respect to both the research base and the availability of investment capital.

Limits to adaptation

The potential for adaptation should not lead to complacency. Agricultural adaptation to climatic variation is not now and may never be perfect, and changes in how farmers

operate or in what they produce may cause significant disruption for people in rural regions. Indeed, some adaptive measures may have detrimental impacts of their own. For example, were major shifts in crops to be made, as from grain to fruit and vegetable production, farmers may find themselves more exposed to marketing problems and credit crises brought on by higher capital and operating costs. The considerable social and economic costs that can result from large- scale climatic extremes was exemplified by the consequences of the Mississippi River flood of 1993.

While changes in planting schedules or in crop varieties may be readily adopted, modifying the types of crops grown does not ensure equal levels of either food production or nutritional quality. Nor can it guarantee equal profits for farmers. Expanded irrigation may lead to groundwater depletion, soil salinization, and waterlogging. Increased demand for water by competing sectors may limit the viability of irrigation as an adaptation to climate change. Expansion of irrigation as a response to climate change will be difficult and costly even under the best circumstances. Mounting societal pressures to reduce environmental damage from agriculture will likely foster an increase in protective regulatory policies that can further complicate the process of adaptation.

Present agricultural institutions and policies in the U.S. tend to discourage farm management adaptation strategies, such as altering the mix of crops that are grown. At the policy level, obstacles to change are created by supporting prices of crops that are not well suited to a changing climate, by providing disaster payments when crops fail, and by restricting competition through import quotas. Programs could be modified to expand the flexibility allowed in crop mixes, to remove institutional barriers to the development of water markets, and to improve the basis for crop disaster payments.

Adaptation cannot be taken for granted: improvements in agriculture have always depended upon on the investment that is made in agricultural research and infrastructure. It would help to identify, through research, the specific ways that farmers now adapt to present variations in climate. Do farmers attempt to compensate for a less favorable climate by applying more fertilizer, more machinery, or more labor? Information of this nature is needed to assess potentialities for coping with more drastic climate change. Success in adapting to possible future climate change will depend on a better definition of what changes will occur where, and on prudent investments, made in timely fashion, in adaptation strategies.