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Weathering Global Warming in Agriculture

by Douglas Southgate
Project Director: Julian Morris

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Executive Summary

This study investigates the potential consequences of climate change for global agricultural output and identifies policies that would reduce any negative impacts. Some researchers have estimated that climate change resulting from manmade global warming could reduce agricultural output significantly (compared to baseline assumptions), especially in tropical countries. As a result, food prices would rise and malnutrition worsen. However, these estimates assume minimal or no adaptation to changes in the climate. In particular, they assume that farmers will fail to switch crops, modify their use of water and other inputs, and adopt new technology. This view is unrealistic: faced with changing conditions, farmers will adapt – unless prohibited.

The study identifies what can and should be done to minimize the impact of climate change on crop production, including:

- Improved water management
- Development and adoption of new crops
- Development and adoption of other new technologies

However, the study notes that currently there are numerous barriers inhibiting the right sort of adaptation, in particular:

- Subsidies to agricultural inputs and outputs, resulting in over-production and, in the case of biofuels, unnecessary diversion of crops to non-food uses.

- Political control of water supplies, which results in under-pricing of water (effectively an input subsidy), undermining incentives both to conserve water (leading to overuse) and to develop new supplies. This is likely to cause particular problems if the world warms and increases in evaporation exceed increases in precipitation.
- Politically imposed restrictions on trade.
- Politically imposed restrictions on the use of new agricultural technologies.

In order to ensure more effective adaptation to a changing climate, the study advocates the removal of these barriers by:

- Removing subsidies to agricultural inputs and outputs, including protection and mandates for the production of biofuel.
- Creating secure, transferable ownership of water rights and ensuring that these rights are vested in individuals and groups with an interest in the effective stewardship of that water, which might include irrigators and private water companies. Chile's highly positive experience offers a model in this respect.
- Removing barriers to trade, including restrictions on the import and export of agricultural products.
- Removing burdensome restrictions on the use of modern agricultural technologies. While some regulation may be justified in order to protect health and the environment, in many countries regulations on technologies from pesticides to genetically modified crops are unjustifiably restrictive and result in the use of inferior technologies that are more harmful to health and the environment.

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Part 1

Introduction

Provided it is not a consequence of governmental interference with market forces, cheap food creates far-reaching benefits. People struggling to survive on a dollar or two a day, of whom there are more than two billion around the world, are better able to feed themselves. Diminished food scarcity also leads to increased expenditures on goods and services other than food, thereby accelerating the economic diversification that is an integral feature of development. Moreover, low prices facilitate the savings required for investment and economic growth.[1]

Declining food scarcity has helped drive overall economic progress for decades, even as the demand for edible goods has been increasing at a fast clip. Since the middle of the twentieth century, when the population was slightly less than 2.5 billion, human numbers have shot up, surpassing 6.0 billion shortly before 2000 and currently approaching 7.0 billion. Adding to food demand have been pronounced improvements in living standards, especially in China and other Asian nations where much of the population could not afford adequate sustenance little more than a generation ago. Yet food supplies have more than kept pace—mainly thanks to technological advances during and since the Green Revolution that have caused global yields of cereals (which comprise at least 60 percent of the human diet if the grain consumed by livestock is taken into account) to rise by 150 percent since the early 1960s.[2]

The general tendency of food supplies to overwhelm food demand has registered in the marketplace. Corrected for inflation, prices of corn, rice and wheat declined by approximately 75 percent between 1950 and the middle 1980s, and then remained at historically low levels for another two decades.[3] Food prices spiked in 2007 and 2008 due to rising agricultural production costs resulting from higher energy prices, expanded conversion of corn and other crops into biofuels, and export restrictions implemented by nations such as Argentina, Ukraine and Vietnam. However, markets soon returned to normal, with prices in late 2008 a little above what they had been before the spike.

Occasional upswings like those of 2007 and 2008 notwithstanding, food prices can remain at current levels or even decline further in the years to come. For example, the World Bank anticipates a deceleration of demand growth, mainly because population increases will dwindle as human fertility continues to decline and because the rate of growth for grain consumption per capita promises to slow down in emerging economies.[4] In addition, ample opportunities remain for boosting production.[5] Under the Bank's baseline scenario, real food prices should be slightly below current levels in 2050, when human numbers will be at around nine billion and close to stabilizing.[6]

But there are caveats. If governments continue to subsidize and mandate biofuel production, mid-century prices of crops could be 30 percent above current levels[7]. Also, food could grow scarcer *if* global warming impairs agricultural productivity.[8] Increased scarcity would weigh heavily on the poor, who spend most of their meager earnings on food. According to one group of researchers, as many as 26 million more impoverished children could be malnourished in 2050 because of adverse developments in agriculture resulting from climate change.[9] The question is: will global warming impair agricultural productivity?

Part 2

Agricultural Production and Climate Change

The consequences of higher global temperatures, which the U.N. Intergovernmental Panel on Climate Change (IPCC) anticipates will come about because of increased atmospheric concentrations of carbon dioxide and other greenhouse gasses, have been the subject of much investigation. These consequences defy precise measurement due to the difficulties of predicting what the climate will be in the future as well as the impacts on agricultural yields of changing temperatures, shifting patterns of precipitation, increased carbon-fertilization (which as a rule accelerates plant growth) and sea-level rise. Moreover, economic evaluation requires factoring in adaptation, which in the agricultural sector involves changing from one crop to another, combining inputs in different ways, and developing and using new technology.

The earliest assessments of the impacts of climate change on crop and livestock production focused largely on affluent and temperate settings, such as the United States.[10] One reason for this emphasis is that breadbaskets in temperate latitudes—including the American Midwest, the Ukrainian countryside, and the Argentine Pampas—produce much of the world's grain (aside from rice) and are the source of most cereals traded in international markets. Furthermore, higher temperatures might create drier conditions in the interiors of North America and the Eurasian landmass, thereby reducing harvests.[11]

To assess the agricultural impacts of climate change, in temperate latitudes and elsewhere, many economists have concentrated on rural land values, since these ought to rise if farmers adapt successfully to environmental flux and fall if agricultural productivity suffers. In one study, modest warming was projected to have limited effects on the prices of agricultural real estate in the United States.[12] A more recent study focused on the eastern two-thirds of the U.S., where agriculture is mainly rain-fed. Schlenker et al. determined that rural land values would be lower in most of the region, given that rain-fed yields would decline and that commodity prices would not be greatly affected by global climate change.[13]

The IPCC, which has assessed impacts on the food economy as well, expects temperature increases in the range of 1 to 3°C later this century to have small yet beneficial effects on agricultural productivity and crop yields in temperate settings as well as the high latitudes, including Canada and Siberia. But closer to the equator, especially in dry areas, productivity and yields are expected to fall even if temperatures increase by just 1 to 2°C in a few decades.[14] This is consistent with the observation made by Kane et al. that, due to elevated evapotranspiration, substantial crop-stress can result in the tropics and subtropics from a minor rise in temperatures.[15]

Other investigators agree that global warming will probably do more harm in the low latitudes than in settings farther from the equator. In one recent assessment, yields of various crops in different parts of the developing world have been estimated for 2050, assuming that warming occurs and also based on different projections of precipitation and carbon-fertilization (Table 1). In East Asia and Latin America, where wheat is raised mainly in temperate environments with adequate rainfall, per-hectare output of that crop is expected to rise. In contrast, global warming will reduce wheat yields in the Middle East and North Africa, South Asia, as well as south of the Sahara. In addition, rice and corn yields are expected to fall due to climate change throughout the developing world, dramatically so in some regions.

It should be emphasized that findings of the sort reported in Table 1 do not account for agricultural adaptation, so provide an exaggerated perspective on climate-change damages. In particular, estimates of yield declines tend to be based on the assumption that agricultural technology remains fixed—to be specific, no new technology is developed, even in the face of environmental flux, and farmers do not change practices. These assumptions are clearly unrealistic; even if no new technologies were developed, farmers would undoubtedly change their practices as temperatures rise and as rainfall patterns shift.

Table 1: Potential Percentage Changes in Crop Yields in 2050 Due to Global Warming

	Rice	Wheat	Corn
East Asia	-11 to -8	+2	-13 to +9
Latin America and Caribbean	-22 to -19	+11 to +17	-4 to 0
Middle East and North Africa	-40 to -33	-9 to -5	-10 to -7
South Asia	-15 to -14	-49 to -44	-19 to -9
Sub-Saharan Africa	-15	-6 to -34	-10 to -7

Source: G. Nelson, M. Rosegrant, J. Koo, et al., *Climate Change: Impact on Agriculture and Costs of Adaptation*, Washington D.C.: International Food Policy Research Institute, 2009, p. 9.

Going beyond the estimation of yield declines in the absence of technological development and adaptation, Kurukulasuriya et al. have investigated the likely effects of climate change on net revenues for African agriculture,[16] using an approach similar to what Mendelsohn et al. employed in the aforementioned study of rural land values in the United States. A 1-percent increase in average temperature is found to reduce net revenues for dryland farming, which predominates in Africa, by 1.9 percent. The adverse impact on net revenues for the livestock sector is even greater: a decline of 5.4 percent. In contrast, net revenues for irrigated agriculture in the world's poorest continent go up by 0.5 percent.[17]

In principle, it would be possible to compensate for productivity losses in agriculture, which are indicated by declining net revenues. For example, it has been estimated that increased spending of $3 billion per year on rural roads and other infrastructure would allow Sub-Saharan Africa to deal with the agricultural impacts of climate change. Likewise, declines in average calorie availability and per-capita grain production in Asia could be avoided by increasing annual investment in irrigation systems and other public works by $2.5 billion. The effects of climate change are expected to be milder in Latin America and the Caribbean, so a little more than $1 billion spent each year on agricultural research, irrigation efficiency and rural infrastructure should allow the region to cope.[18]

Part 3

Adaptation, Markets and Public Policy

Along with a number of other investigators, Nelson et al. focus on investments that governments can undertake to ameliorate the adverse consequences of higher temperatures and altered patterns of precipitation.[19] However, adaptation also occurs on individual farms—adaptation that is conditioned by the prices growers receive for output as well as the prices they pay for inputs, especially water.

Free markets would provide the best price signals to guide individual responses to climate change. Consider for example farmers in a country who have competed successfully in the global wheat market in the past, but are unable to do so now because of higher prevailing temperatures. Economic logic dictates that those farmers should shift to the production of other products—to be specific, crops that can be grown profitably in the changed climate. If there are no trade restrictions, this will happen. Meanwhile, to the extent that people demand wheat, it will be imported at lower cost than it could be produced locally.

But just as free trade promotes efficient adaptation to climate change, governmental interference with market forces discourages farmers from changing from one crop to another, altering practices and otherwise going about their work differently. Consider again the country that can no longer compete in the international wheat market due to global warming. The government might choose to "protect" its wheat growers by taxing or otherwise blocking imports. This would harm the country's consumers since they would be forced to pay more for products such as bread and noodles. Moreover, resources that ought to be harnessed for the production of other crops would continue to be tied up in wheat farming. The resulting inefficiencies would be compounded if the country's trading partners erected their own trade barriers. In short, protectionism would stifle the realignment of productive factors around the world needed for agriculture to cope with climate change.

Mendelsohn underscores the desirability of free trade and the harm done by protectionism in a world experiencing higher temperatures and shifting patterns of precipitation.[20] The same can be said of efficient water markets and irrigation subsidies.

Much lip service is paid to the importance of hydrologic resources and, if magazine covers and newspaper headlines are any guide, worries about a global water crisis are acute and widespread.

Yet water is treated in most places as if it has no economic value whatsoever. The prices paid by urban households and other customers of municipal water companies tend to fall short of the cost of building, operating and maintaining canals, pumping stations and other infrastructure. Even more extreme are the subsidies in rural areas.

During the Green Revolution, which began in the middle 1960s and continued into the 1980s, governments in Asia and other developing regions were keen to encourage the spread of new varieties of rice and wheat that produce more grain than traditional varieties if water and fertilizer are applied. They did so by providing those inputs to farmers either for free or at token prices.[21] The benefits of this policy have been undeniable, counted as these are in terms of the hundreds of millions of lives saved because agricultural output has more than kept pace with food demand at a time of peak growth in human numbers. However, subsidization has resulted in the overuse of some inputs, especially water. Agricultural use of hydrologic resources in Asia swelled during the Green Revolution and remains exaggerated (Table 2).

Table 2: Water Availability and Agricultural Water Use in 2007

	Renewable freshwater resources (billion m^3)	Annual freshwater withdrawals (billion m^3)	Agriculture's share of freshwater withdrawals (%)
High-income nations	9,516	921	43%
East and Southeast Asia	9,454	959	74%
South Asia	1,819	941	89%
Latin America and Caribbean	13,425	265	71%
Middle East and North Africa	225	276	86%
Eastern Europe and Former Soviet Union	5,167	368	60%
Sub-Saharan Africa	3,858	120	87%
World	43,464	3,850	70%

Source: World Bank 2009, Global Economic Prospects: Commodities at the Crossroads, Washington.

Irrigation subsidies create waste and inefficiency on a grand scale. Consider the case of India. Farmers in the world's second most populous nation pay nothing for water diverted from rivers, released from reservoirs, or extracted from underground aquifers. Public authorities also provide the electricity needed to run their pumps and other equipment at little or no charge. With irrigation agencies collecting no revenues from farmers, maintenance of dams and other infrastructure is deficient. Moreover, commodity price supports combine with irrigation subsidies to encourage the production of rice, which is a water-intensive crop. This further accelerates groundwater depletion in some of the driest parts of the country.[22]

Whatever the inefficiencies suffered today because vital hydrologic resources are treated as worthless, the costs are sure to compound if those resources become appreciably scarcer, as many predict will happen due to climate change.

Part 4

Poor Cost Recovery and the Magnitude of Inefficient Pricing

Discussions of inefficient water pricing in the food economy tend to focus on poor cost recovery in systems belonging to the public sector, which irrigate more land than private systems in most countries. The term “cost recovery” refers to the gap between prices and the expenses of building, operating and maintaining the dams, canals and other infrastructure needed to transport water from its various sources to farmers’ fields and other points of consumption.

However, the underpricing of water in the agricultural sector has additional dimensions. For pricing to be entirely efficient, two additional costs must be factored in, aside from infrastructure expenses. One of these costs has to do with protecting water sources—conserving watersheds, in other words. The second reflects tradeoffs in the use of hydrologic resources. The tradeoffs (or opportunity costs) of irrigation can be sizable if households, industry and other non-agricultural users would be willing to pay much for the water diverted to crop or livestock production or rendered unfit for consumption after being used by farmers.

If cost recovery is poor, the public authorities that own and manage irrigation systems are unable to finance watershed conservation or the treatment of agricultural water pollution. In a worldwide review of irrigation subsidies, Malik finds that affluent countries belonging to the Organization for Economic Cooperation and Development (OECD) tend to charge irrigation fees that fall short of operation and maintenance costs.[23] As a result, investment expenses, watershed conservation costs and wastewater treatment expenses are all completely subsidized. Likewise, there is no accounting for the values of non-agricultural uses of hydrologic resources.

Cost recovery is below 40 percent in China. However, some local authorities in that nation have become financially autonomous, which tends to encourage investment aimed at improving the reliability of water supplies. Since this reliability is valued by farmers, price increases needed to improve cost recovery can be implemented. However, there is little evidence in China that prices reflect either the costs of watershed conservation or the opportunity costs of hydrologic resources made available to farmers.[24]

In other settings, cost recovery and subsidies are worse. In Egypt, where rain-fed agriculture is unknown, farmers in the Nile River Valley and other irrigated settings pay nothing for water.[25] Surveying the pricing of hydrologic resources in different parts of the world, one must conclude that the inefficiencies in India mentioned above may be extreme, but are by no means exceptional.

Part 5

The Challenge of Irrigation Reform

In addition to diagnosing pricing inefficiencies, Malik offers suggestions for the correct pricing of water.[26] This requires watershed conservation to be taken into account, along with the opportunity costs of irrigation. Externalities (or spillovers) must be considered as well. For example, withdrawals by one irrigator from an aquifer shared by many farmers raise these farmers' costs. To avoid misallocation due to this sort of externality, every irrigator must pay a price that reflects the higher costs that others (including other farmers) incur as resources are depleted.

Aside from the difficulties of estimating the various costs of irrigation, raising irrigation fees, as is needed to cover at least a portion of these costs, is usually problematical. The reason for this is that irrigation subsidies, like other subsidies, end up inflating land values. One way to appreciate this linkage is to think about a hypothetical valley where all farming has been rain-fed in the past. Once an irrigation system is put in place, yields go up and agricultural profits rise. Especially if water is underpriced, bids for agricultural land increase correspondingly.

Let us now reform irrigation policy in the hypothetical valley. The main consequence of higher prices for water at the farm level is to reduce agricultural profits, which in turn lowers land prices. Some farmers are bound to oppose the reform simply out of regret for the lost financial windfall that cheap water has provided them. But other farmers have a greater stake in continuing the subsidy. If they have borrowed money to buy real estate, at prices driven up by cheap-water policies, then higher irrigation fees will subject them to financial hardship. Some of them might even go bankrupt—in particular if the value of their real estate, which is the main asset for most farmers, falls below the outstanding balance of their mortgages.

Recognizing the financial consequences of higher water prices for farmers, many advocates of reform settle for a partial approach. To be specific, irrigation systems formerly owned and managed by the central government are handed over to local associations of irrigators, who must then see to operations and maintenance on their own. Such an approach improves the recovery of non-capital costs. It can also raise agricultural output and incomes, if better management of irrigation systems makes more resources available to farmers or improves the reliability of water supplies. However, it is typical for the capital costs of devolved systems to be written off entirely, not paid by irrigators in whose hands these systems have been placed. Neither does devolution address issues such as paying for watershed conservation and covering the opportunity costs of irrigation.

As long as irrigators do not internalize all capital, environmental and opportunity costs, waste and misallocation can still be substantial. Farmers in non-irrigated settings are bound to continue lobbying for expensive new projects, knowing that the tab for investment will be picked up by government and not themselves. By the same token, not internalizing the expenses of watershed protection and the opportunity costs of irrigation development will still add to the political pressure for new projects, even if these are not efficient.

One of the few places to wrestle seriously with issues such as these is Chile, which has facilitated the internalization of capital, environmental and opportunity costs by creating private and transferable rights in water. The key reform in that South American nation was the Water Code of 1981, which replaced prior legislation that had the effect of socializing hydrologic resources. Consistent with Article 19 in the 1980 constitution, the 1981 Code established that individual prerogatives in water are property rights in every sense of the term, provided that ownership has been officially adjudicated by the country's General Water Directorate (DGA). In addition to being permanent, water rights are transferable, sales being allowed either among farmers or between agricultural and non-agricultural users. These rights can also be mortgaged and cannot be expropriated without due compensation, although a tax on unused rights has been in effect since 1 January 2006 .[27]

Farmers and other water users have responded to this regime by filing for DGA adjudication of their claims. Thousands of claims have been recognized to date, so a large share of the country's resources is in private hands. Buying and selling of water rights have been more limited, although spot markets have been harnessed to alleviate scarcity during years with below-normal precipitation.[28] In addition, farmers have sold water rights to potable-water companies.[29] Thanks to this sort of transaction, the opportunity costs of irrigation are no longer ignored in Chile, as happens routinely in most other places.

Part 6

Conclusions

The debate over global warming often seems to create more heat than light. While there is evidence that temperatures have risen over the post century, questions remain concerning future increases and the degree to which humanity is responsible. The likely effects of climate change are even more contentious.

Notwithstanding the considerable uncertainties involved in estimating future changes in climate, this paper has sought to identify suitable policies to address the problem as it relates to agriculture. All available evidence suggests that farmers can adapt to modest warming (of up to 3°C) at a modest cost. The investments needed to compensate for higher temperatures and shifting patterns of precipitation in Africa, Asia and Latin America are not inordinately large. In addition, adaptation to climate change—by individual farmers, entire nations and ultimately the world as a whole—requires reforms that are pro-market and pro-technology.

- Efficient accommodation of environmental flux of global dimensions depends on shifts in cropping patterns, input use and so forth on a global scale. The latter shifts are hindered by agricultural protectionism by individual countries, so climate change increases the importance of trade liberalization in the food economy.

- Hydrologic resources, which are treated as valueless in most of the world, are expected to grow scarcer as the years pass, especially with global warming. At the very least, better cost recovery is needed in public irrigation systems, which account for a large share of overall water use in the tropics and subtropics. As indicated in this report, one way to accomplish this is for central governments to hand over these systems to local associations of irrigators. However, efficient pricing of irrigation water should also be pursued by creating ownership rights in hydrologic resources that are secure and transferable. Chilean experience demonstrates that water markets, which can function only if such rights exist, facilitate internalization of the opportunity costs of resource use and development.

- Drier conditions, which will be observed in many parts of the world because of climate change, will strengthen the demand for drought-resistant varieties. At a minimum, ungrounded opposition to the biotechnological processes that create these varieties must be confronted.

If agriculture suffers because of climate change, the fault will lie not with underlying environmental scarcity, but rather with the absence of reforms such as these—reforms for which the case could hardly be more compelling.

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Douglas Southgate is a natural resource economist with a Ph.D. from the University of Wisconsin, and has been a faculty member at Ohio State University since 1980. His research focuses mainly on environmental issues in the developing world, such as tropical deforestation and the economics of watershed management. Along with numerous journal articles and scholarly papers, Dr. Southgate is the author of four books, including *The World Food Economy* (2nd edition, 2010, Wiley-Blackwell). He also has consulted for the World Bank, the Inter-American Development Bank, the U.S. Agency for International Development and the Ford Foundation in 14 Latin American and Caribbean nations.

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