ISSUE 13

Are Improved Aid Policies the Best Way to Improve Global Food Supply and Protect World Population?

YES: Robert Paarlberg, from "Evaluating, and Improving, America's Response to Global Hunger," testimony before the Senate Committee on Foreign Relations Hearing on "Alleviating Global Hunger: Challenges and Opportunities for U.S. Leadership" (March 24, 2009)

NO: Lester R. Brown, from "Could Food Shortages Bring Down Civilization?" *Scientific American* (May 2009)

ISSUE SUMMARY

YES: Professor Robert Paarlberg argues that global hunger, which afflicts nearly a billion people worldwide, many of them in Africa, calls for increased aid directed toward agricultural education, science, and research, and infrastructure development.

NO: Lester R. Brown argues that the problem is due more to water shortages, soil losses, rising population, and rising temperatures from global warming than to failures of aid policies. What is needed is immediate attention to the world's environmental problems, lacking which the result will be increased hunger, political conflict, and perhaps even the collapse of civilization.

In 1798 the British economist Thomas Malthus published his *Essay on the Principle of Population.* In it, he pointed with alarm at the way the human population grew geometrically (a hockey-stick curve of increase) and at how agricultural productivity grew only arithmetically (a straight-line increase). It was obvious, he said, that the population must inevitably outstrip its food supply and experience famine. Contrary to the conventional wisdom of the time, population growth was not necessarily a good thing. Indeed, it led inexorably to catastrophe. For many years, Malthus was something of a laughingstock. The doom he forecast kept receding into the future as new lands were opened

to agriculture, new agricultural technologies appeared, new ways of preserving food limited the waste of spoilage, and the developed nations underwent a "demographic transition" from high birthrates and high death rates to low birthrates and low death rates.

Demographers initially attributed the demographic transition to increasing prosperity and predicted that as prosperity increased in countries whose populations were rapidly growing, birthrates would surely fall. Later, some scholars analyzed the historical data and concluded that the transition had actually preceded prosperity. The two views have contrasting implications for public policy designed to slow population growth—economic aid or family planning aid—but neither has worked very well. In 1994 the UN Conference on Population and Development, held in Cairo, Egypt, concluded that better results would follow from improving women's access to education and health care.

The world's human population has grown tremendously. In Malthus's time, there were about 1 billion human beings on earth. By 1950 there were a little over 2.5 billion. In 2007 the tally passed 6.7 billion. By 2050, the United Nations expects world population to be over 9 billion (see *World Population Prospects: The 2008 Revision;* http://www.un.org/esa/population/unpop.htm; United Nations, 2009).

While global agricultural production has also increased, it has not kept up with rising demand, and—because of the loss of topsoil to erosion, the exhaustion of aquifers for irrigation water, the high price of energy for making fertilizer, and the expected effects of global warming (among other things)—the prospect of improvement seems exceedingly slim to many observers. Paul R. Ehrlich and Anne H. Ehrlich argue in "The Population Explosion: Why We Should Care and What We Should Do About It," *Environmental Law* (Winter 1997) that "population growth may be the paramount force moving humanity inexorably towards disaster." They therefore maintain that it is essential to reduce the impact of population in terms of both numbers and resource consumption. See also William G. Moseley, "A Population Remedy Is Right Here at Home: U.S. Overconsumption Is a Bigger Issue than Fertility," *The Philadelphia Inquirer* (July 11, 2007).

Was Malthus wrong? Both environmental scientists and many economists now say that if population continues to grow, problems are inevitable. But the problem is not just a mismatch between population growth and agricultural production. More and more, scientists are seeing that this mismatch is exacerbated by loss of resources such as soil and water that are absolutely essential to agriculture. In the following selections, Wellesley College Professor Robert Paarlberg argues that global hunger, which currently afflicts nearly a billion people worldwide, calls for increased aid directed toward agricultural education, science, and research, and infrastructure development. Lester R. Brown argues that the problem is due more to water shortages, soil losses, rising population, and rising temperatures from global warming than to failures of aid policies. We need to stabilize population and eradicate poverty, but lacking immediate attention to the world's environmental problems, we are likely to see increased hunger, political conflict, and perhaps even the collapse of civilization.

YES — Robert Paarlberg

Evaluating, and Improving, America's Response to Global Hunger

Providing international leadership to alleviate global hunger requires our Government to have strong policies in two separate areas:

- Responding to short-term food emergencies, such as the international food price spike we saw in 2008, which temporarily put up to 100 million more people at risk.
- Attacking the persistent poverty that keeps more than 850 million people hungry even when international food prices are low.

In the first of these areas, the United States Government has done a good job, at least a B+. But in the second area the U.S. has done a poor job over the past 25 years, something close to an F. In 2009 America has a chance to correct this second failing grade by directing more development assistance support to help small farmers in Sub-Saharan Africa and South Asia. Until the productivity of these small farmers goes up, poverty and hunger will not go down.

America's Laudable Response to the 2008 World Food Crisis

When the price of food on the world market suddenly surged upward during the first six month of 2008, it was clear that some developing countries heavily dependent on imported food needed help. In April 2008 the World Bank produced an estimate that an additional 100 million people in the developing world were being pushed into effective poverty because of the much higher food import prices. The New York Times called these high prices a "World Food Crisis." The Economist called it a "Silent Tsunami."

This was a serious crisis for poor countries heavily dependent on food imports, particularly in West Africa and the Caribbean, but not all developing countries fell into that category. Many governments in the developing world have long made it a point not to depend on imports of basic grains (in the name of national food "self-sufficiency"). For example in South Asia only about 6 percent of total grain consumption is imported, and in India

U.S. Senate, March 24, 2009.

specifically only 1 percent of rice consumption is imported. So when the price of rice for export tripled in 2008 it was a shock in Cameroon and Haiti, but it had little effect on most poor people in India.

International food prices spiked as high as they did precisely because so many developing country governments decided not to let higher international prices cross into their own domestic economy. When export prices starting increasing in 2007, one country after another insulated its domestic market from the increase by placing new restrictions on food exports. China imposed export taxes on grains and grain products. Argentina raised export taxes on wheat, corn and soybeans. Russia raised export taxes on wheat. Malaysia and Indonesia imposed export taxes on palm oil. Egypt, Cambodia, Vietnam, and Indonesia eventually banned exports of rice. India, the world's third largest rice exporter, banned exports of rice other than basmati. When so many export restrictions were suddenly set in place, the quantity of food available for export dropped sharply, triggering the large price spike seen in international markets.

The response of the United States Government to this price spike was timely and commendable. America provided essential global leadership, in two important ways.

First, the United States never placed any restrictions on its own exports of agricultural commodities. While others were imposing export taxes or export bans, the United States continued to leave its domestic food supply open to foreign customers. This was not an easy discipline to maintain. America's decision to place no restriction on its own rice exports meant prices inside the U.S. economy spiked upward along with the international price, which led to an interlude of panic buying. In April 2008, Costco Wholesale Corporation and Wal-Mart's Sam's Club had to limit sales of rice to 4 bags per customer per visit. For wheat, the U.S. decision not to restrict exports implied much higher operating costs for America's baking industry, prompting the American Bakers Association early in 2008 to send delegations to Washington to voice loud complaint. Despite these domestic pressures, our Government never restricted export sales.

Second, when international prices spiked in 2008 the United States dramatically increased its budget for international food aid. In April 2008, President Bush announced the release of $200 million worth of commodities from an emergency food aid reserve for Title II PL480, and then in May 2008 the President requested from Congress an additional $770 million as a crisis response, with roughly 80 percent of this intended to help poor importing governments or support short term feeding of vulnerable populations. According to one unofficial calculation, the United States responded to the 2008 crisis by designating an additional $1.4 billion in food aid above already planned funding levels. Total enacted and estimated international food assistance spending from the United States in FY2009 will be roughly $2 billion.

Our policy response to the 2008 food price spike was far from perfect, in part because our food aid programs are unnecessarily expensive. This is because the United States does not allow any significant sourcing of food from outside of the United States and because shipment on more costly U.S.-flag vessels is required for 75 percent of all gross food aid tonnage. As a result an excessive 65 percent of America's food aid spending goes to administrative and transport costs. Some economists calculate that it costs roughly twice as much to deliver a ton of food to a recipient through this U.S. food aid system as it would cost buying the food from a local market. The United States is heavily criticized abroad for operating its food aid programs this way. On the other hand, if America went to a more efficient system based on foreign sourcing, political support for the program here in Congress would suffer, the size of our food aid budget would fall, and food deliveries to some needy recipients abroad might then fall as well.

America was also heavily criticized in 2008 for the alleged impact of its biofuels policies on world food prices. Federal tax credits, import tariffs, and renewable fuel mandates promoted the diversion of American corn into fuel production, driving up international prices for corn used as food or feed. In 2007–08, ethanol production increased to roughly 23 percent of America's total corn use. On the other hand, much of this diversion would have taken place in 2008 even without any U.S. Government tax credits, tariffs, or mandates, simply due to the unusually high oil prices that prevailed at the time. When bad things happen it is not always the government's fault. It was mostly high oil prices, not government policy, that drove up corn use for ethanol in 2008.

America's Less Helpful Response to Persistent Hunger

America has shown far less leadership in its policy response to the long-term problem of chronic malnutrition in developing countries. This hunger problem, linked especially to rural poverty, is roughly eight times larger than the temporary problem linked to the 2007–08 price spike.

Even before international food prices began to increase in 2007, the United Nations Food and Agriculture Organization (FAO) estimated that there were 850 million chronically malnourished people in the world. Even when food was cheap on the world market in 2005, in Sub-Saharan Africa 23 out of 37 countries in that region were consuming less than their nutritional requirements and nearly one third of all citizens there were malnourished. The problem of hunger in these countries derives primarily from persistent poverty, not from price fluctuations on the world market. In Africa more than 60 percent of all citizens work in the countryside growing crops and herding animals, and it is because the productivity of their labor is so low (incomes average only about $1 a day) that so many are chronically malnourished.

To understand the source of these low incomes, pay a visit to a typical farming community in rural Africa. The farmers you will meet, mostly women, do not have any of the things that farmers everywhere else have required to become more productive and escape poverty:

- Few have had access to formal education. Two out of three adults are not able to read or write in any language.
- Two thirds do not have access to seeds improved by scientific plant breeding.

- Most use no nitrogen fertilizer at all, so they fail to replace soil nutrients and their crop yields per hectare are only one fifth to one tenth as high as in the United States or in Europe.
- Only 4 percent have irrigation, so when the rains fail their crops also fail, and they must sell off their animals and household possessions to survive until the next season.
- Almost none have access to electricity, and powered machinery is completely absent. These farmers still work the fields with hand hoes or wooden plows pulled by animals.
- Few have access to veterinary medicine, so their animals are sick, stunted, and weak.
- Most of these farmers are significantly cut off from markets due to remoteness and high transport costs. Roughly 70 percent of African farmers live more than a half-hour walk from the nearest all-weather road, so most household transport is still by foot.

Given such deficits, it is not surprising that agricultural production in Africa has lagged behind population growth for most of the past three decades. Per capita production of maize, Africa's most important food staple, has actually *declined* 14 percent since 1980. Over the same time period population has doubled, so the numbers of people living in deep poverty (less than $1 a day) has doubled as well, up to 300 million. The number of Africans classified as "food insecure" by the U.S. Department of Agriculture increased to 450 million in 2006, and under a business-as-usual scenario this number will grow by another 30 percent over the next ten years, to reach 645 million.

One reason the current business-as-usual scenario is so bleak has been weak leadership from the United States. Instead of taking action to help address these persistent farm productivity deficits in Africa over the past several decades, the United States Government essentially walked away from the problem:

- America's official development assistance to agriculture in Africa, in real 2008 dollars, declined from more than $400 million annually in the 1980s to just $60 million by 2006, a drop of approximately 85 percent.
- Between 1985 and 2008 the number of Africans supported by USAID for post-graduate agricultural study at American universities declined 83 percent, down to a total of just 42 individuals today.
- From the mid-1980s to 2004, USAID funding to support national agricultural research systems (NARS) in the developing countries as a whole fell by 75 percent, and in Sub-Saharan Africa by 77 percent.
- From the mid-1980s to 2008, United States contributions to the core research budget of the Consultative Group on International Agricultural Research (CGIAR), in real 2008 dollars, fell from more than $90 million annually to just $18.5 million.
- USAID spending for collaborative agricultural research through American universities was nearly $45 million in constant 2008 dollars twenty five years ago. As of 2007, this funding was down to just $25 million.
- These cuts were accompanied by severe agricultural de-staffing at USAID. As late as 1990 USAID still employed 181 agricultural specialists. Currently it employs only 22.

So, while Africa's rural poverty and hunger crisis was steadily growing worse, the United States Government was steadily doing less.

Why Did the United States Stop Investing in Agricultural Development?

Beginning in the 1980s, three factors combined to push the United States away from providing adequate assistance for agricultural development:

First, the enormous success of the original Green Revolution on the irrigated lands of Asia in the 1960s and 1970s left a false impression that all of the world's food production problems had been solved. In fact, on the non-irrigated farmlands of Africa, these problems were just beginning to intensify.

Second, it became fashionable among most donors beginning in the 1980s to rely less on the public sector and more on the private sector, under a so-called "Washington Consensus" doctrine developed inside the IMF and the World Bank. According to this new aid doctrine, the job of the state was mostly to stabilize the macro economy and then get out of the way, so private investors and private markets could create wealth. This approach backfired in rural Africa because the basic public goods needed to support markets and attract private investors—roads, power, and an educated workforce—had not yet been provided.

Third, a new fashion also arose in the 1980s among advocates for social justice and environmental protection. These groups began to depict the improved seeds and fertilizers of the original Green Revolution as a problem, not a solution. They argued that only large farmers would profit and that increased chemical use would harm the environment. This perspective was not appropriate in Africa, where nearly all farmers are smallholders with adequate access to land and where fertilizer use is too low rather than too high. In Africa the social and environmental danger isn't too much Green Revolution farming, but far too little.

I have documented the importance of these NGO objections to Green Revolution farming in a book published last year by Harvard University Press. I show in this book that an influential coalition of social justice and environmental advocates from both North America and Europe was able to discourage international support for agricultural development, including in Africa, beginning in the 1980s. They not only opposed the use of modern biotechnology, such as genetic engineering; they also campaigned against conventionally developed modern seeds and nitrogen fertilizers, even though these were precisely the technologies their own farmers had earlier used back home to become more productive and escape poverty. To Africans they instead promoted agroecological or organic farming methods, not using synthetic pesticides or fertilizers.

The irony is that most farmers in Africa today are already de facto organic, because they do not use any GMOs, or any nitrogen fertilizers, or any synthetic pesticides. This has not made them either productive or prosperous. Nor has it provided any protection to Africa's rural environment, where deforestation, soil erosion, and habitat loss caused by the relentless expansion of low-yield farming is a growing crisis.

How to Correct America's Failing Grade in Agricultural Development

Improving America's dismal policy performance in the area of agricultural development does not have to be difficult. We know what to do, we know it can be done at an affordable cost, and the current political climate even provides new space to act.

A consensus now exists among specialists, even at the World Bank, on what to do. An extensive review conducted by the Bank in preparation for its 2008 *World Development Report* concluded that more public sector action was urgently needed: "the visible hand of the state" was now needed to provide the "core public goods" essential to farm productivity growth. Three kinds of public goods are needed today in the African countryside:

- Public investments in rural and agricultural education, including for women and girls.
- Public investments in agricultural science and local agricultural research to improve crops, animals, and farming techniques.
- Public investments in rural infrastructure (roads, electricity, crop storage) to connect farmers to markets.

Governments in Africa today endorse this consensus. At an African Union summit meeting in Mozambique in 2003, Africa's heads of government pledged to increase their own public spending on agriculture up to at least 10 percent of total national spending. International donors, including the United States, should seize upon this constructive pledge, redirecting assistance efforts so as to partner aggressively with African governments willing to re-invest in the productivity of small farms.

We know exactly what this re-directed assistance effort should look like, thanks to the policy roadmap recently provided by two members of this committee plus the supportive recommendations of a prominent independent study group.

The widely endorsed Global Food Security Act of 2009 (S. 3529), known as the Lugar-Casey bill, would authorize significantly larger investments in agricultural education, extension, and research, to take full international advantage of the superior agricultural resources found within of America's own land grant colleges and universities. The increased investments in institutional strengthening and collaborative research authorized in this bill could be funded at $750 million in year one, increasing to an annual cost of $2.5 billion by year five. Fully funding this initiative would require roughly a 10 percent increase in America's annual development assistance budget, a small increase alongside President Obama's own 2008 campaign pledge—which I strongly endorse—to grow that development assistance budget by 100 percent.

A second worthy blueprint strongly parallels the Lugar-Casey bill. This is a menu of 21 separate recommended actions called the Chicago Initiative on Global Agricultural Development, released just one month ago by an independent bipartisan study group convened by the Chicago Council on Global

Affairs, with financial support from the Bill and Melinda Gates Foundation. This substantial report, which I played a role in preparing, recommends twin thrusts in agricultural education and agricultural research, just like Lugar-Casey. It also recommends closer coordination with the World Bank to increase investments in rural infrastructure, plus a substantial upgrade of agricultural staff at USAID. The Chicago Council report estimates that implementing all 21 of its recommended actions would cost $341 million in the first year (an increase over current programs of $255 million), and only $1.03 billion annually by year five (an increase of $950 million over current expenditures). This implies less than a 5 percent increase in our current development assistance budget.

Why Is 2009 the Best Time to Take These Actions?

The danger is not that Congress will debate these proposals and then reject them as too costly. Both of these proposals are well researched and substantively well defended, and the implied costs are not at all large alongside the anticipated humanitarian, economic, and diplomatic gains. The danger instead is that a serious debate over these proposals will never take place, amid the many distractions of the day, and a decision will simply be deferred. This would be a costly mistake. If new action is deferred, the business-as-usual scenario will kick in and numbers of food insecure people in Sub-Saharan Africa will increase by another 30 percent over the next ten years, to reach a total of 645 million. If the new Administration and Congress decide to put off action until 2013 or 2017, the hunger problem will only become more costly to resolve.

Fortunately, two important windows of political opportunity are open in 2009 to support the embrace of a significant policy initiative in this area. First, both the new Administration and Congress are eager to be seen delivering a "real change" in America's policies abroad, not just at home. A decision in 2009 to reverse, at last, the 25-year decline in U.S. support for agricultural development assistance would be a real change, and it would be recognized as such around the world. It would transform America overnight from being the laggard in this area into being the global leader. With its new agricultural development initiative on the table, America could re-introduce itself to governments around the world—especially in Africa—with a convincing message of hope, not fear. The payoff in farmers' fields would not be seen immediately, but the political and diplomatic gain would be immediate.

For those on this committee looking for an affordable way to recast America's approach toward governments in Africa (e.g., in response to China's growing investment presence and political influence in that region), a new agricultural development initiative is actually one of the most cost-effective ways to proceed. The annual budget cost is low because the best way to support agricultural development is not with a massive front-loaded crash program, but instead with small but steady annual outlays developed and managed in close partnership with recipient governments, maintained for a decade or more.

The second window of opportunity was provided by the 2008 food price crisis itself. Memories of this crisis are still sufficiently fresh in 2009 to motivate action on a significant new agricultural development assistance initiative, to complement the strong leadership we already show in emergency relief and food aid.

Both these windows of political opportunity are currently open. They are not likely to remain open for long.

Lester R. Brown

NO

Could Food Shortages Bring Down Civilization?

One of the toughest things for people to do is to anticipate sudden change. Typically we project the future by extrapolating from trends in the past. Much of the time this approach works well. But sometimes it fails spectacularly, and people are simply blindsided by events such as today's economic crisis.

For most of us, the idea that civilization itself could disintegrate probably seems preposterous. Who would not find it hard to think seriously about such a complete departure from what we expect of ordinary life? What evidence could make us heed a warning so dire—and how would we go about responding to it? We are so inured to a long list of highly unlikely catastrophes that we are virtually programmed to dismiss them all with a wave of the hand: Sure, our civilization might devolve into chaos—and Earth might collide with an asteroid, too!

For many years I have studied global agricultural, population, environmental and economic trends and their interactions. The combined effects of those trends and the political tensions they generate point to the breakdown of governments and societies. Yet I, too, have resisted the idea that food shortages could bring down not only individual governments but also our global civilization.

I can no longer ignore that risk. Our continuing failure to deal with the environmental declines that are undermining the world food economy—most important, falling water tables, eroding soils and rising temperatures—forces me to conclude that such a collapse is possible.

The Problem of Failed States

Even a cursory look at the vital signs of our current world order lends unwelcome support to my conclusion. And those of us in the environmental field are well into our third decade of charting trends of environmental decline without seeing any significant effort to reverse a single one.

In six of the past nine years world grain production has fallen short of consumption, forcing a steady drawdown in stocks. When the 2008 harvest began, world carryover stocks of grain (the amount in the bin when the new harvest begins) were at 62 days of consumption, a near record low. In response, world grain prices in the spring and summer of last year climbed to the highest level ever.

As demand for food rises faster than supplies are growing, the resulting food-price inflation puts severe stress on the governments of countries already teetering on the edge of chaos. Unable to buy grain or grow their own, hungry people take to the streets. Indeed, even before the steep climb in grain prices in 2008, the number of failing states was expanding [Purchase the digital edition to see related sidebar]. Many of their problems stem from a failure to slow the growth of their populations. But if the food situation continues to deteriorate, entire nations will break down at an ever increasing rate. We have entered a new era in geopolitics. In the 20th century the main threat to international security was superpower conflict; today it is failing states. It is not the concentration of power but its absence that puts us at risk.

States fail when national governments can no longer provide personal security, food security and basic social services such as education and health care. They often lose control of part or all of their territory. When governments lose their monopoly on power, law and order begin to disintegrate. After a point, countries can become so dangerous that food relief workers are no longer safe and their programs are halted; in Somalia and Afghanistan, deteriorating conditions have already put such programs in jeopardy.

Failing states are of international concern because they are a source of terrorists, drugs, weapons and refugees, threatening political stability everywhere. Somalia, number one on the 2008 list of failing states, has become a base for piracy. Iraq, number five, is a hotbed for terrorist training. Afghanistan, number seven, is the world's leading supplier of heroin. Following the massive genocide of 1994 in Rwanda, refugees from that troubled state, thousands of armed soldiers among them, helped to destabilize neighboring Democratic Republic of the Congo.

Our global civilization depends on a functioning network of politically healthy nation-states to control the spread of infectious disease, to manage the international monetary system, to control international terrorism and to reach scores of other common goals. If the system for controlling infectious diseases—such as polio, SARS or avian flu—breaks down, humanity will be in trouble. Once states fail, no one assumes responsibility for their debt to outside lenders. If enough states disintegrate, their fall will threaten the stability of global civilization itself.

A New Kind of Food Shortage

The surge in world grain prices in 2007 and 2008—and the threat they pose to food security—has a different, more troubling quality than the increases of the past. During the second half of the 20th century, grain prices rose dramatically several times. In 1972, for instance, the Soviets, recognizing their poor harvest early, quietly cornered the world wheat market. As a result, wheat prices elsewhere more than doubled, pulling rice and corn prices up with them. But this and other price shocks were event-driven—drought in the Soviet Union, a monsoon failure in India, crop-shrinking heat in the U.S. Corn Belt. And the rises were short-lived: prices typically returned to normal with the next harvest.

In contrast, the recent surge in world grain prices is trend-driven, making it unlikely to reverse without a reversal in the trends themselves. On the demand side, those trends include the ongoing addition of more than 70 million people a year; a growing number of people wanting to move up the food chain to consume highly grain-intensive livestock products [see "The Greenhouse Hamburger," by Nathan Fiala; *Scientific American*, February 2009]; and the massive diversion of U.S. grain to ethanol-fuel distilleries.

The extra demand for grain associated with rising affluence varies widely among countries. People in low-income countries where grain supplies 60 percent of calories, such as India, directly consume a bit more than a pound of grain a day. In affluent countries such as the U.S. and Canada, grain consumption per person is nearly four times that much, though perhaps 90 percent of it is consumed indirectly as meat, milk and eggs from grain-fed animals.

The potential for further grain consumption as incomes rise among low-income consumers is huge. But that potential pales beside the insatiable demand for crop-based automotive fuels. A fourth of this year's U.S. grain harvest—enough to feed 125 million Americans or half a billion Indians at current consumption levels—will go to fuel cars. Yet even if the entire U.S. grain harvest were diverted into making ethanol, it would meet at most 18 percent of U.S. automotive fuel needs. The grain required to fill a 25-gallon SUV tank with ethanol could feed one person for a year.

The recent merging of the food and energy economies implies that if the food value of grain is less than its fuel value, the market will move the grain into the energy economy. That double demand is leading to an epic competition between cars and people for the grain supply and to a political and moral issue of unprecedented dimensions. The U.S., in a misguided effort to reduce its dependence on foreign oil by substituting grain-based fuels, is generating global food insecurity on a scale not seen before.

Water Shortages Mean Food Shortages

What about supply? The three environmental trends I mentioned earlier—the shortage of freshwater, the loss of topsoil and the rising temperatures (and other effects) of global warming—are making it increasingly hard to expand the world's grain supply fast enough to keep up with demand. Of all those trends, however, the spread of water shortages poses the most immediate threat. The biggest challenge here is irrigation, which consumes 70 percent of the world's freshwater. Millions of irrigation wells in many countries are now pumping water out of underground sources faster than rainfall can recharge them. The result is falling water tables in countries populated by half the world's people, including the three big grain producers—China, India and the U.S.

Usually aquifers are replenishable, but some of the most important ones are not: the "fossil" aquifers, so called because they store ancient water and are not recharged by precipitation. For these—including the vast Ogallala Aquifer that underlies the U.S. Great Plains, the Saudi aquifer and the deep aquifer under the North China Plain—depletion would spell the end of pumping. In arid regions such a loss could also bring an end to agriculture altogether.

In China the water table under the North China Plain, an area that produces more than half of the country's wheat and a third of its corn, is falling fast. Overpumping has used up most of the water in a shallow aquifer there, forcing well drillers to turn to the region's deep aquifer, which is not replenishable. A report by the World Bank foresees "catastrophic consequences for future generations" unless water use and supply can quickly be brought back into balance.

As water tables have fallen and irrigation wells have gone dry, China's wheat crop, the world's largest, has declined by 8 percent since it peaked at 123 million tons in 1997. In that same period China's rice production dropped 4 percent. The world's most populous nation may soon be importing massive quantities of grain.

But water shortages are even more worrying in India. There the margin between food consumption and survival is more precarious. Millions of irrigation wells have dropped water tables in almost every state. As Fred Pearce reported in *New Scientist*:

> Half of India's traditional hand-dug wells and millions of shallower tube wells have already dried up, bringing a spate of suicides among those who rely on them. Electricity blackouts are reaching epidemic proportions in states where half of the electricity is used to pump water from depths of up to a kilometer [3,300 feet].

A World Bank study reports that 15 percent of India's food supply is produced by mining groundwater. Stated otherwise, 175 million Indians consume grain produced with water from irrigation wells that will soon be exhausted. The continued shrinking of water supplies could lead to unmanageable food shortages and social conflict.

Less Soil, More Hunger

The scope of the second worrisome trend—the loss of topsoil—is also startling. Topsoil is eroding faster than new soil forms on perhaps a third of the world's cropland. This thin layer of essential plant nutrients, the very foundation of civilization, took long stretches of geologic time to build up, yet it is typically only about six inches deep. Its loss from wind and water erosion doomed earlier civilizations.

In 2002 a U.N. team assessed the food situation in Lesotho, the small, landlocked home of two million people embedded within South Africa. The team's finding was straightforward: "Agriculture in Lesotho faces a catastrophic future; crop production is declining and could cease altogether over large tracts of the country if steps are not taken to reverse soil erosion, degradation and the decline in soil fertility."

In the Western Hemisphere, Haiti—one of the first states to be recognized as failing—was largely self-sufficient in grain 40 years ago. In the years since, though, it has lost nearly all its forests and much of its topsoil, forcing the country to import more than half of its grain.

The third and perhaps most pervasive environmental threat to food security—rising surface temperature—can affect crop yields everywhere. In many countries crops are grown at or near their thermal optimum, so even a minor temperature rise during the growing season can shrink the harvest. A study published by the U.S. National Academy of Sciences has confirmed a rule of thumb among crop ecologists: for every rise of one degree Celsius (1.8 degrees Fahrenheit) above the norm, wheat, rice and corn yields fall by 10 percent.

In the past, most famously when the innovations in the use of fertilizer, irrigation and high-yield varieties of wheat and rice created the "green revolution" of the 1960s and 1970s, the response to the growing demand for food was the successful application of scientific agriculture: the technological fix. This time, regrettably, many of the most productive advances in agricultural technology have already been put into practice, and so the long-term rise in land productivity is slowing down. Between 1950 and 1990 the world's farmers increased the grain yield per acre by more than 2 percent a year, exceeding the growth of population. But since then, the annual growth in yield has slowed to slightly more than 1 percent. In some countries the yields appear to be near their practical limits, including rice yields in Japan and China.

Some commentators point to genetically modified crop strains as a way out of our predicament. Unfortunately, however, no genetically modified crops have led to dramatically higher yields, comparable to the doubling or tripling of wheat and rice yields that took place during the green revolution. Nor do they seem likely to do so, simply because conventional plant-breeding techniques have already tapped most of the potential for raising crop yields.

Jockeying for Food

As the world's food security unravels, a dangerous politics of food scarcity is coming into play: individual countries acting in their narrowly defined self-interest are actually worsening the plight of the many. The trend began in 2007, when leading wheat-exporting countries such as Russia and Argentina limited or banned their exports, in hopes of increasing locally available food supplies and thereby bringing down food prices domestically. Vietnam, the world's second-biggest rice exporter after Thailand, banned its exports for several months for the same reason. Such moves may reassure those living in the exporting countries, but they are creating panic in importing countries that must rely on what is then left of the world's exportable grain.

In response to those restrictions, grain importers are trying to nail down long-term bilateral trade agreements that would lock up future grain supplies. The Philippines, no longer able to count on getting rice from the world market, recently negotiated a three-year deal with Vietnam for a guaranteed 1.5 million tons of rice each year. Food-import anxiety is even spawning entirely new efforts by food-importing countries to buy or lease farmland in other countries.

In spite of such stopgap measures, soaring food prices and spreading hunger in many other countries are beginning to break down the social order. In several provinces of Thailand the predations of "rice rustlers" have forced villagers to guard their rice fields at night with loaded shotguns. In Pakistan an armed soldier escorts each grain truck. During the first half of 2008, 83 trucks carrying grain in Sudan were hijacked before reaching the Darfur relief camps.

No country is immune to the effects of tightening food supplies, not even the U.S., the world's breadbasket. If China turns to the world market for massive quantities of grain, as it has recently done for soybeans, it will have to buy from the U.S. For U.S. consumers, that would mean competing for the U.S. grain harvest with 1.3 billion Chinese consumers with fast-rising incomes—a nightmare scenario. In such circumstances, it would be tempting for the U.S. to restrict exports, as it did, for instance, with grain and soybeans in the 1970s when domestic prices soared. But that is not an option with China. Chinese investors now hold well over a trillion U.S. dollars, and they have often been the leading international buyers of U.S. Treasury securities issued to finance the fiscal deficit. Like it or not, U.S. consumers will share their grain with Chinese consumers, no matter how high food prices rise.

Plan B: Our Only Option

Since the current world food shortage is trend-driven, the environmental trends that cause it must be reversed. To do so requires extraordinarily demanding measures, a monumental shift away from business as usual—what we at the Earth Policy Institute call Plan A—to a civilization-saving Plan B.

Similar in scale and urgency to the U.S. mobilization for World War II, Plan B has four components: a massive effort to cut carbon emissions by 80 percent from their 2006 levels by 2020; the stabilization of the world's population at eight billion by 2040; the eradication of poverty; and the restoration of forests, soils and aquifers.

Net carbon dioxide emissions can be cut by systematically raising energy efficiency and investing massively in the development of renewable sources of energy. We must also ban deforestation worldwide, as several countries already have done, and plant billions of trees to sequester carbon. The transition from fossil fuels to renewable forms of energy can be driven by imposing a tax on carbon, while offsetting it with a reduction in income taxes.

Stabilizing population and eradicating poverty go hand in hand. In fact, the key to accelerating the shift to smaller families is eradicating poverty—and vice versa. One way is to ensure at least a primary school education for all children, girls as well as boys. Another is to provide rudimentary, village-level health care, so that people can be confident that their children will survive to adulthood. Women everywhere need access to reproductive health care and family-planning services.

The fourth component, restoring the earth's natural systems and resources, incorporates a worldwide initiative to arrest the fall in water tables by raising water productivity: the useful activity that can be wrung from each drop. That implies shifting to more efficient irrigation systems and to more water-efficient crops. In some countries, it implies growing (and eating) more wheat and less rice, a water-intensive crop. And for industries and cities, it implies doing what some are doing already, namely, continuously recycling water.

At the same time, we must launch a worldwide effort to conserve soil, similar to the U.S. response to the Dust Bowl of the 1930s. Terracing the ground, planting trees as shelterbelts against windblown soil erosion, and practicing minimum tillage—in which the soil is not plowed and crop residues are left on the field—are among the most important soil-conservation measures.

There is nothing new about our four interrelated objectives. They have been discussed individually for years. Indeed, we have created entire institutions intended to tackle some of them, such as the World Bank to alleviate poverty. And we have made substantial progress in some parts of the world on at least one of them—the distribution of family-planning services and the associated shift to smaller families that brings population stability.

For many in the development community, the four objectives of Plan B were seen as positive, promoting development as long as they did not cost too much. Others saw them as humanitarian goals—politically correct and morally appropriate. Now a third and far more momentous rationale presents itself: meeting these goals may be necessary to prevent the collapse of our civilization. Yet the cost we project for saving civilization would amount to less than $200 billion a year, a sixth of current global military spending. In effect, Plan B is the new security budget.

Time: Our Scarcest Resource

Our challenge is not only to implement Plan B but also to do it quickly. The world is in a race between political tipping points and natural ones. Can we close coal-fired power plants fast enough to prevent the Greenland ice sheet from slipping into the sea and inundating our coastlines? Can we cut carbon emissions fast enough to save the mountain glaciers of Asia? During the dry season their meltwaters sustain the major rivers of India and China—and by extension, hundreds of millions of people. Can we stabilize population before countries such as India, Pakistan and Yemen are overwhelmed by shortages of the water they need to irrigate their crops?

It is hard to overstate the urgency of our predicament. [For the most thorough and authoritative scientific assessment of global climate change, see "Climate Change 2007. Fourth Assessment Report of the Intergovernmental Panel on Climate Change," available at www.ipcc.ch]. Every day counts. Unfortunately, we do not know how long we can light our cities with coal, for instance, before Greenland's ice sheet can no longer be saved. Nature sets the deadlines; nature is the timekeeper. But we human beings cannot see the clock.

We desperately need a new way of thinking, a new mind-set. The thinking that got us into this bind will not get us out. When Elizabeth Kolbert, a writer for the *New Yorker,* asked energy guru Amory Lovins about thinking outside the box, Lovins responded: "There is no box."

There is no box. That is the mind-set we need if civilization is to survive.

POSTSCRIPT

Are Improved Aid Policies the Best Way to Improve Global Food Supply and Protect World Population?

Global hunger is a much more enormous problem than most people realize. In a special report on the food crisis, Joel K. Bourne, Jr., "The End of Plenty," *National Geographic* (June 2009), says that we need another green revolution, and in half the time it took to implement the first one. The human population faces a major shortage of essential resources needed to satisfy its need for food, including soil (see Charles Mann, "Our Good Earth: Can We Save It?" *National Geographic,* September 2008) and water (see David Molden, Charlotte de Fraiture, and Frank Rijsberman, "Water Scarcity: The Food Factor," *Issues in Science and Technology,* Summer 2007), and "Perhaps somewhere deep in his crypt . . . Malthus is quietly wagging a bony finger and saying, "Told you so."

P. M. Schmitz and A. Kavallari, "Crop Plants versus Energy Plants—On the International Food Crisis," *Bioorganic & Medicinal Chemistry* (June 2009), argue that demand-driven food shortages can be overcome through proper design of agricultural policy. Testifying at the same Senate hearing as Robert Paarlberg, Dan Glickman and Catherine Bertini describe the Chicago Council on Global Affairs' Global Agricultural Development Project and its report, *Renewing American Leadership in the Fight Against Global Hunger and Poverty* (February 2009). Like Paarlberg, Glickman and Bertini emphasize supporting agricultural education and research and infrastructure development, as well as strengthening aid institutions and improving aid policy. They do not mention environmental problems or suggest addressing them. Sir Gordon Conway, "The Food Crisis," *The Geographical Journal* (vol. 174, No. 3, 2008), pays more attention to water shortages and rising temperatures when he calls for a "Doubly Green Revolution" that would bring to the world's farms drought-tolerant, pest-resistant, disease-resistant crop plants.

Aid, education, research, policy, and technology are all going to be needed. But as Lester R. Brown notes, population is also an important factor. Resources and population come together in the concept of "carrying capacity," defined very simply as the size of the population that the environment can support, or "carry," indefinitely, through both good years and bad. It is not the size of the population that can prosper in good times alone, for such a large population must suffer catastrophically when droughts, floods, hurricanes, or blights arrive or the climate warms or cools. It is a long-term concept, where "long-term" means not decades or generations, nor even centuries, but millennia or more. See Mark Nathan Cohen, "Carrying Capacity," *Free Inquiry* (August/September 2004). It is worth noting that many see the threat of global warming and its accompanying changes in rainfall patterns, sea level, and disease distribution as the beginning of a long run of bad years. See Sarah DeWeerdt, "Climate Change, Coming Home," *World Watch* (May/June 2007), and Jeffrey D. Sachs, "Climate Change Refugees," *Scientific American* (June 2007).

Elizabeth Leahy and Sean Peoples, "Projecting Population," *World Watch* (May/June 2009), remind us that it is difficult to predict future population levels, for our projections depend on assumptions and can be very wrong. Among those assumptions must be counted our estimates of future availability of water, soil, energy, and other resources. It is even harder to estimate Earth's carrying capacity for human beings. It is surely impossible to set a precise figure on the number of human beings the world can support for the long run. As Joel E. Cohen discusses in *How Many People Can the Earth Support?* (W. W. Norton, 1995), estimates of Earth's carrying capacity range from under a billion to over a trillion. The precise number depends on our choices of diet, standard of living, level of technology, willingness to share with others at home and abroad, and desire for an intact physical, chemical, and biological environment, as well as on whether or not our morality permits restraint in reproduction and our political or religious ideology permits educating and empowering women. The key, Cohen stresses, is human choice, and the choices are ones we must make within the next 50 years. See also Joel E. Cohen, "Human Population Grows Up," *Scientific American* (September 2005). Phoebe Hall, "Carrying Capacity," *E Magazine* (March/April 2003), notes that even countries with large land areas and small populations, such as Australia and Canada, can be overpopulated in terms of resource availability. The critical resource appears to be food supply; see Russell Hopfenberg, "Human Carrying Capacity Is Determined by Food Availability," *Population & Environment* (November 2003). Jared Diamond's *Collapse: How Societies Choose to Fail or Succeed* (Viking, 2005) is an excellent presentation of how past societies have run afoul of the need to match resources and population.

Andrew R. B. Ferguson, in "Perceiving the Population Bomb," *World Watch* (July/August 2001), sets the maximum sustainable human population at about 2 billion. Sandra Postel, in the Worldwatch Institute's *State of the World 1994* (W. W. Norton, 1994), says, "As a result of our population size, consumption patterns, and technology choices, we have surpassed the planet's carrying capacity. This is plainly evident by the extent to which we are damaging and depleting natural capital" (including soil and water).

According to current population projections, the population growth rate is decreasing and global population may level off and even begin to decline by the end of this century. But the question of carrying capacity remains. Most estimates of carrying capacity put it at well below the current world population size, and it will take a long time for global population to fall far enough to reach such levels. We seem to be moving in the right direction, but it remains an open question whether our numbers will decline far enough soon enough,

i.e., before environmental problems become critical. On the other hand, Jeroen Van den Bergh and Piet Rietveld, "Reconsidering the Limits to World Population: Meta-analysis and Meta-prediction," *Bioscience* (March 2004), set their best estimate of human global carrying capacity at 7.7 billion, which is distinctly reassuring.

ISSUE 14

Is Genetic Engineering the Answer to Hunger?

YES: Gerald D. Coleman, from "Is Genetic Engineering the Answer to Hunger?" *America* (February 21, 2005)

NO: Sean McDonagh, from "Genetic Engineering Is Not the Answer," *America* (May 2, 2005)

ISSUE SUMMARY

YES: Gerald D. Coleman argues that genetically engineered crops are useful, healthful, and nonharmful, and although caution may be justified, such crops can help satisfy the moral obligation to feed the hungry.

NO: Sean McDonagh argues that those who wish to feed the hungry would do better to address land reform, social inequality, lack of credit, and other social issues.

In the early 1970s scientists first discovered that it was technically possible to move genes—the biological material that determines a living organism's physical traits—from one organism to another and thus (in principle) to give bacteria, plants, and animals new features. Most researchers in molecular genetics were excited by the potentialities that suddenly seemed within their reach. However, a few researchers—as well as many people outside the field—were disturbed by the idea; they thought that genetic mix-and-match games might spawn new diseases, weeds, and pests. Researchers in support of genetic experimentation responded by declaring a moratorium on their own work until suitable safeguards (in the form of government regulations) could be devised.

A 1987 National Academy of Sciences report said that genetic engineering posed no unique hazards. And, despite continuing controversy, by 1989 the technology had developed tremendously: researchers could obtain patents for mice with artificially added genes ("transgenic" mice); firefly genes had been added to tobacco plants to make them glow (faintly) in the dark; and growth hormone produced by genetically engineered bacteria was being used to grow low-fat pork and increase milk production in cows. The growing biotechnology industry promised more productive crops that made their own

fertilizer and pesticide. Proponents argued that genetic engineering was in no significant way different from traditional selective breeding. Critics argued that genetic engineering was unnatural and violated the rights of both plants and animals to their "species integrity"; that expensive, high-tech, tinkered animals gave the competitive advantage to big agricultural corporations and drove small farmers out of business; and that putting human genes into animals, plants, or bacteria was downright offensive. Trey Popp, "God and the New Foodstuffs," *Science & Spirit* (March/April 2006), discusses objections to genetically modified rice containing human genes. For a summary of events related to the development of agricultural biotechnology, see "Biotechnology Timeline: Chronology of Key Events," *International Debates* (March 2006).

In 1992 the U.S. Office of Science and Technology issued guidelines to bar regulations that are based on the assumption that genetically engineered crops pose greater risks than similar crops produced by traditional breeding methods. The result was the rapid commercial introduction of crops that were genetically engineered to make the bacterial insecticide Bt and to resist herbicides and disease, among other things. Rice has now been engineered for herbicide and stress resistance, attempts have been made to improve nutrient content and yield, and "Transgenic rice can serve as a biofactory for the production of molecules of pharmaceutical and industrial utility. The drive to apply transgenic rice for public good as well as commercial gains has fueled research to an all time high"; see Hitesh Kathuria, et al., "Advances in Transgenic Rice Biotechnology," *Critical Reviews in Plant Sciences* (2007). In 2008, some 70 engineered crop varieties were grown on over 125 million hectares (308 million acres) in 25 countries (see GMO-Compass.org, http://www.gmo-compass.org/eng/agri_biotechnology/gmo_planting/). Commercial GM crops are chiefly soybeans, corn, cotton, and canola. Sales of genetically engineered crop products are expected to reach $210 billion by 2014.

Skepticism about the benefits remains, but in 2000, the national academies of science of the United States, the United Kingdom, China, Brazil, India, Mexico, and the third world recognized that though the use of genetically modified crops has some worrisome potentials that deserve further research and continuing caution, those crops hold the potential to feed the world during the twenty-first century while also protecting the environment (Royal Society of London, et al., "Transgenic Plants and World Agriculture," July 2000; http://books.nap.edu/catalog.php?record_id=9889). Genetic engineering is also poised to improve turfgrass and help produce biofuels (see Derek Burke, "Biofuels—Is There a Role for GM?" *Biologist*, February 2007).

The following selections illustrate the different current perspectives from within the Roman Catholic Church. Gerald D. Coleman argues that genetically engineered crops are useful, healthful, and nonharmful, and though caution may be justified, such crops can help satisfy the moral obligation to feed the hungry. Sean McDonagh, a priest who writes frequently on environmental matters, argues that ethical and environmental problems connected to the implementation of genetically engineered crops stand in the way of their promise. Those who wish to feed the hungry would do better to address land reform, social inequality, lack of credit, and other social issues.

YES

Gerald D. Coleman

Is Genetic Engineering the Answer to Hunger?

Both the developed and developing worlds are facing a critical moral choice in the controversial issue of genetically modified food, also known as genetically modified organisms and genetically engineered crops. Critics of these modifications speak dismissively of biotech foods and genetic pollution. On the other hand, proponents like Nina Federoff and Nancy Marie Brown, authors of *Mendel in the Kitchen: A Scientist's View of Genetically Modified Foods* (2004), promote genetically modified organisms (GMs or GMOs) as "the miracle of seed science and fertilizers."

To mark the 20th anniversary of U.S. diplomatic relations with the Holy See, the U.S. Embassy to the Holy See, in cooperation with the Pontifical Academy of Sciences, hosted a conference last fall at Rome's Gregorian University on "Feeding a Hungry World: The Moral Imperative of Biotechnology." Archbishop Renato Martino, who heads the Pontifical Council for Justice and Peace and has been a strong and outspoken proponent of GMOs, told Vatican Radio: "The problem of hunger involves the conscience of every man. For this reason the Catholic Church follows with special interest and solicitude every development in science to help the solution of a plight that affects . . . humanity."

Americans have grown accustomed, perhaps unwittingly, to GMO products. In the United States, for example, 68 percent of the soybeans, 70 percent of the cotton crop, 26 percent of corn and 55 percent of canola are genetically engineered. GMOs represent an estimated 60 percent of all American processed foods. A recent study by the National Center for Food and Agriculture found that farmers in the United States investing in biotech products harvested 5.3 billion additional pounds of crops and realized $22 billion in increased income. Most of the world's beer and cheese is made with GMOs, as are hundreds of medications. In an article published last October, James Nicholson, then U.S. Ambassador to the Vatican and an aggressive promoter of U.S. policy in Vatican circles, wrote that "millions of Americans, Canadians, Australians, Argentines and other people have been eating genetically modified food for nearly a decade—without one proven case of an illness, allergic reaction or even the hiccups. . . . Mankind has been genetically altering food throughout human history." And according to its supporters, biotechnology helps the environment by reducing the use of pesticides and tilling.

From *America*, vol. 192, Feb. 21, 2005, p. 14.

The World Health Association recently reported that more than 3.7 billion people around the world are now malnourished, the largest number in history. To this, opponents of GMOs reply that the "real problems" causing hunger, especially in the developing world, are poverty, lack of education and training, unequal land distribution and lack of access to markets. The moral point they advance is that distribution, not production, is the key to solving hunger.

Another significant moral issue relates to "intellectual property policies" and the interest of companies in licensing potentially valuable discoveries. The Rev. Giulio Albanese, head of the Missionary News Agency, insists that unless the problem of intellectual property is resolved in favor of the poor, it represents a "provocation" to developing countries: "The concern of many in the missionary world over the property rights to GM seeds . . . cannot but accentuate the dependence of the poor nations on the rich ones." In response to this concern, a proposal was made recently (reported in *Science* magazine on March 19) that research universities cooperate to seek open licensing provisions that would allow them to share their intellectual property through a "developing-country license." Universities would still retain rights for research and education and maintain negotiating power with the biotechnology and pharmaceutical industries. Catholic social ethics would support this type of proposal, since it places the good of people over amassing profit.

Three moral paths suggest themselves:

1. *Favor the use of GMOs.* Nobel Prize winner Norman Borlaug, who developed the Green Revolution wheat and rice strains, recently wrote: "Biotechnology absolutely should be part of Africa's agricultural reform. African leaders would be making a grievous error if they turn their back on it." Proponents at the Rome conference agreed, arguing that the use of GMOs decreases pesticide use, creates more nutrient-filled crops that require less water and have greater drought resistance, produces more food at a lower cost and uses less land. One small-scale South African farmer concluded, "We need this technology. We don't want always to be fed food aid. We want access to this technology so that one day we can also become commercial farmers."

   This position concludes that the use of GMOs amounts to a moral obligation.
2. *Condemn the use of GMOs.* Many Catholic bishops take an opposing stance. Perhaps the clearest statement comes from the National Conference of Bishops of Brazil and their Pastoral Land Commission. Their argument is threefold: the use of GMOs involves potential risks to human health; a small group of large corporations will be the greatest beneficiaries, with grave damage to the family farmers; and the environment will be gravely damaged.

   The bishops of Botswana, South Africa and Swaziland agree: "We do not believe that agro-companies or gene technologies will help our farmers to produce the food that is needed in the 21st century." Roland Lesseps and Peter Henriot, two Jesuits working in Zambia who are experts on agriculture in the developing world, state their opposition on principle: "Nature is not just useful to us as humans, but is valued and loved in itself, for itself, by God in Christ. . . . The right to use other creatures does not give us the right to abuse them."

In a similar but distinct criticism, the executive director of the U.S. National Catholic Rural Conference, David Andrews, C.S.C., feels that "the Pontifical Academy of Sciences has allowed itself to be subordinated to the U.S. government's insistent advocacy of biotechnology and the companies which market it." Sean McDonagh states: "With patents [on genetically engineered food], farmers will never own their own food. . . ." He believes that "corporate greed" is at the heart of the GMO controversy. Biowatch's Elfrieda Pschorn-Strauss agrees: "With GM crops, small-scale farmers will become completely reliant on and controlled by big foreign companies for their food supply."

This position concludes that the use of GMOs is morally irresponsible.

3. *Approach the use of GMOs with caution.* Two years ago Pope John Paul II declared that GMO agriculture could not be judged solely on the basis of "short-term economic interests," but needed to be subject to "a rigorous scientific and ethical process of verification." This cautionary stance has been adopted by the Catholic Bishops Conference of the Philippines in urging its government to postpone authorization of GMO corn until comprehensive studies have been made: "We have to be careful because, once it is there, how can we remedy its consequences?"

In 2003 the Rural Life Committee of the North Dakota Conference of Churches also called for "rigorous examination" to understand fully the outcomes of the use of GMOs. This document endorses the "Precautionary Principle" formulated in 1992 by the United Nations Conference on Environment and Development in order to avoid "potential harm and unforeseen and unintended consequences."

This view mandates restraint and places the fundamental burden on demonstrating safety. The arguments are based on three areas of concern: the impact on the natural environment, the size of the benefit to the small farmer if the owners and distributors are giant companies like Bristol-Myers and Monsanto and the long-term effects of GMOs on human and animal health and nutrition.

This position concludes that the use of GMOs should be approached with caution.

While the "Precautionary Principle" seems prudent, there is simultaneously a strong moral argument that a war on hunger is a grave, universal need. Last year, 10 million people died of starvation. Every 3.6 seconds someone dies from hunger—24,000 people each day. Half of sub-Saharan Africans are malnourished, and this number is expected to increase to 70 percent by 2010. It was a moral disgrace that in 2002 African governments gave in to GMO opponents and returned to the World Food Program tons of GMO corn simply because it was produced in the U.S. by biotechnology.

The Roman conference gives solid reasons that GMOs are useful, healthful and nonharmful. After all, organisms have been exchanging genetic information for centuries. The tomato, corn and potato would not exist today if human engineering had not transferred genes between species.

The *Catechism of the Catholic Church* teaches that we have a duty to "make accessible to each what is needed to lead a truly human life." The very first example given is food. In *Populorum Progressio* (1967), *Sollicitude Rei Socialis* (1987) and *Centesimus Annus* (1991), Paul VI and later John Paul II forcefully insisted that rich countries have an obligation to help the poor, just as global economic interdependence places us on a moral obligation to be in solidarity with poor nations. Likewise, *The Challenge of Faithful Citizenship,* published by the U.S. bishops in 2004, argues that the church's preferential option for the poor entails "a moral responsibility to commit ourselves to the common good at all levels."

At the same time, it is critical that farmers in developing countries not become dependent on GMO seeds patented by a small number of companies. Intellectual knowledge must be considered the common patrimony of the entire human family. As the U.S. bishops have stated, "Both public and private entities have an obligation to use their property, including intellectual and scientific property, to promote the good of all people" (*For I Was Hungry and You Gave Me Food, 2003*).

The Catholic Church sees deep sacramental significance in wheat and bread, and insists on the absolute imperative to feed and care for the poor of the world. A vital way to promote and ensure the dignity of every human being is to enable them to have their daily bread.

Sean McDonagh — NO

Genetic Engineering Is Not the Answer

In 1992 the then-chief executive of Monsanto, Robert Shapiro, told the *Harvard Business Review* that genetically modified crops will be necessary to feed a growing world population. He predicted that if population levels were to rise to 10 billion, humanity would face two options: either open up new land for cultivation or increase crop yields. Since the first choice was not feasible, because we were already cultivating marginal land and in the process creating unprecedented levels of soil erosion, we would have to choose genetic engineering. This option, Shapiro argued, was merely a further improvement on the agricultural technologies that gave rise to the Green Revolution that saved Asia from food shortages in the 1960s and 1970s.

Genetically engineered crops might seem an ideal solution. Yet both current data and past examples show problems and provoke doubts as to their necessity.

The Green Revolution

The Green Revolution involved the production of hybrid seeds by crossing two genetically distant parents, which produced an offspring plant that gave increased yield. Critics of genetic engineering question the accepted wisdom that its impact has been entirely positive. Hybrid seeds are expensive and heavily reliant on fertilizers and pesticides. And because they lose their vigor after the first planting, the farmer must purchase new seeds for each successive planting.

In his book *Geopolitics and the Green Revolution*, John H. Perkins describes the environmentally destructive and socially unjust aspects of the Green Revolution. One of its most important negative effects, he says, is that it has contributed to the loss of three-quarters of the genetic diversity of major food crops and that the rate of erosion continues at close to 2 percent per year. The fundamental importance of genetic diversity is illustrated by the fact that when a virulent fungus began to destroy wheat fields in the United States and Canada in 1950, plant breeders staved off disaster by cross-breeding five Mexican wheat varieties with 12 imported ones. In the process they created a new strain that was able to resist so-called "stem rust." The loss of these varieties would have been a catastrophe for wheat production globally.

From *America*, vol. 192, May 2, 2005, p. 8.

The Terminator Gene

The development by a Monsanto-owned company of what is benignly called a Technology Protection System—a more apt name is terminator technology—is another reason for asserting that the feed-the-world argument is completely spurious. Genetically engineered seeds that contain the terminator gene self-destruct after the first crop. Once again, this forces farmers to return to the seed companies at the beginning of each planting season. If this technology becomes widely used, it will harm the two billion subsistence farmers who live mainly in the poor countries of the world. Sharing seeds among farmers has been at the very heart of subsistence farming since the domestication of staple food crops 11,000 years ago. The terminator technology will lock farmers into a regime of buying genetically engineered seeds that are herbicide tolerant and insect resistant, tethering them to the chemical treadmill.

On an ethical level, a technology that, according to Professor Richard Lewontin of Harvard University, "introduces a 'killer' transgene that prevents the germ of the harvested grain from developing" must be considered grossly immoral. It is a sin against the poor, against previous generations who freely shared their knowledge of plant life with us, against nature itself and finally against the God of all creativity. To set out deliberately to create seeds that self-destruct is an abomination no civilized society should tolerate. Furthermore, there is danger that the terminator genes could spread to neighboring crops and to the wild and weedy relatives of the plant that has been engineered to commit suicide. This would jeopardize the food security of many poor people.

The current situation promoting genetically modified organisms also means supporting the patenting of living organisms—both crops and animals. I find it difficult to understand the support that Cardinal Renato Martino, prefect of the Pontifical Council for Justice and Peace, seems to be giving to genetically modified organisms, given the Catholic Church's strong pro-life position. In my book *Patenting Life? Stop!* I argue that "patenting life is a fundamental attack on the understanding of life as interconnected, mutually dependent and a gift of God to be shared with everyone. Patenting opts for an atomized, isolated understanding of life." The Indian scientist and activist Dr. Vandana Shiva believes that patented crops will lead to food dictatorship by a handful of northern transnational corporations. This would certainly be a recipe for hunger and starvation—in conflict with Catholic social teaching on food and agriculture.

No Higher Yield, No Reduction in Chemicals

Early in 2003 a researcher at the Institute of Development Studies at Sussex University in England published an analysis of the GMO crops that biotech companies are developing for Africa. Among the plants studied were cotton, maize and the sweet potato. The GMO research on the sweet potato is now approaching its 12th year and has involved the work of 19 scientists; to date it has cost $6 million. Results indicated that yield has increased by 18 percent. On the other hand, conventional sweet potato breeding, working with a small budget, has produced a virus-resistant variety with a 100 percent yield increase.

Claims that GMOs lead to fewer chemicals in agriculture are also being challenged. A comprehensive study using U.S. government data on the use of chemicals on genetically engineered crops was carried out by Charles Benbrook, head of the Northwest Science and Environmental Policy Center in Sandpoint, Idaho. He found that when GMOs were first introduced, they needed 25 percent fewer chemicals for the first three years. But in 2001, 5 percent more chemicals were sprayed compared with conventional crop varieties. Dr. Benbrook stated: "The proponents of biotechnology claim GMO varieties substantially reduce pesticide use. While true in the first few years of widespread planting, it is not the case now. There's now clear evidence that the average pound of herbicide applied per acre planted to herbicide-tolerant varieties have increased compared to the first few years."

Toward a Solution

Hunger and famine around the world have more to do with the absence of land reform, social inequality, bias against women farmers and the scarcity of cheap credit and basic agricultural tools than with lack of agribusiness super-seeds. This fact was recognized by those who attended the World Food Summit in Rome in November 1996. People are hungry because they do not have access to food production processes or the money to buy food. Brazil, for example, is the third largest exporter of food in the world, yet one-fifth of its population, over 30 million people, do not have enough food to eat. Clearly hunger there is not due to lack of food but to the unequal distribution of wealth and the fact that a huge number of people are landless.

Do the proponents of genetically engineered food think that agribusiness companies will distribute such food free to the hungry poor who have no money? There was food in Ireland during the famine in the 1840s, for example, but those who were starving had no access to it or money to buy it.

As a Columban missionary in the Philippines, I saw something similar during the drought caused by El Niño in 1983. There was a severe food shortage among the tribal people in the highlands of Mindanao. The drought destroyed their cereal crops, and they could no longer harvest food in the tropical forest because it had been cleared during the previous decades. Even during the height of the drought, an agribusiness corporation was exporting tropical fruit from the lowlands. There was also sufficient rice and corn in the lowlands, but the tribal people did not have the money to buy it. Had it not been for food aid from nongovernmental organizations, many of the tribal people would have starved.

In 1990 the World Food Program at Brown University calculated that if the global food harvests over the previous few years were distributed equitably among all the people of the world, it could provide a vegetarian diet for over 6 billion people. In contrast, a meat-rich diet, favored by affluent countries and currently available to the global elite, could feed only 2.6 billion people.

Human society is going to be faced with the option of getting protein from plants or from animals. If we opt for animal protein, the consequence will be a much less equitable world, with increasing levels of human misery.

Those who wish to banish hunger should address the social and economic inequalities that create poverty and not claim that a magic-bullet technology will solve all the problems.

POSTSCRIPT

Is Genetic Engineering the Answer to Hunger?

Kathleen Hart, in *Eating in the Dark* (Pantheon, 2002), expresses horror at the fact that "Frankenfood" is not labeled and that U.S. consumers are not as alarmed by genetically modified foods as European consumers are. The worries—and the scientific evidence to support them—are summarized by Kathryn Brown, in "Seeds of Concern," and Karen Hopkin, in "The Risks on the Table," *Scientific American* (April 2001). In the same issue, Sasha Nemecek poses the question "Does the World Need GM Foods?" to two prominent figures in the debate: Robert B. Horsch, vice president of the Monsanto Corporation and recipient of the 1998 National Medal of Technology for his work on modifying plant genes, says yes; Margaret Mellon, of the Union of Concerned Scientists, says no, adding that much more work needs to be done with regard to safety. The May 2002 U.S. General Accounting Office Report to Congressional Requesters, "Genetically Modified Foods: Experts View Regimen of Safety Tests as Adequate, but FDA's Evaluation Process Could Be Enhanced," urges more attention to verifying safety testing performed by biotechnology companies. Carl F. Jordan, in "Genetic Engineering, the Farm Crisis, and World Hunger," *Bioscience* (June 2002), says that a major problem is already apparent in the way agricultural biotechnology is widening the gap between the rich and the poor. In a special report on the food crisis, Joel K. Bourne, Jr., "The End of Plenty," *National Geographic* (June 2009), says that the need for improved food production is critical. We need another green revolution, and in half the time it took to implement the first one fifty years ago. Sir Gordon Conway, "The Food Crisis," *The Geographical Journal* (vol. 174, No. 3, 2008), pays more attention to water shortages and rising temperatures when he calls for a "Doubly Green Revolution" that would bring to the world's farms drought-tolerant, pest-resistant, disease-resistant crop plants. However, he emphasizes selective breeding and hybridization over genetic engineering. The food crisis is particularly acute in Africa, where traditional farming techniques simply cannot provide enough food for the growing population. David King, chief scientific adviser to the British government, believes that Africa will not be able to feed itself because it has so far failed to adopt genetically modified (GM) crops; see Khadja Sharife, "Is GM Food the Future for Africa?" *New African* (January 2009).

Charles Mann, in "Biotech Goes Wild," *Technology Review* (July/August 1999), discusses the continuing "lack of a rigorous regulatory framework to sort out the risks inherent in agricultural biotech." Margaret Kriz, in "Global Food Fight," *National Journal* (March 4, 2000), describes the January 2000 Montreal meeting, in which representatives of 130 countries reached "an agreement that

requires biotechnology companies to ask permission before importing genetically altered seeds [and] forces food companies to clearly identify all commodity shipments that may contain genetically altered grain." Also see "Environmental Effects of Transgenic Plants: The Scope and Adequacy of Regulation," a report of the National Research Council's Committee on Environmental Impacts Associated With Commercialization of Transgenic Crops (National Academy Press, 2002).

Gregory Conko and C. S. Prakash, in "The Attack on Plant Biotechnology," in Ronald Bailey, ed., *Global Warming and Other Eco-Myths: How the Environmental Movement Uses False Science to Scare Us to Death* (Prima, 2002), say that genetically engineered crops have successfully increased yields and decreased pesticide usage, have not had notable bad environmental side effects, and will be essential for feeding the world's growing population. Jerry D. Glover, Cindy M. Cox, and John P. Reganold, "Future Farming: A Return to Roots?" *Scientific American* (August 2007), argue that current work aimed at using biotechnology to turn present annual crops such as corn, wheat, and rice into perennial crops will boost the food supply while greatly reducing soil erosion and water pollution. Lee Silver, "Why GM Is Good for Us," *Newsweek (Atlantic Edition)* (March 20, 2006), reports that genetically modified foods may actually have fewer allergy-related problems than organic foods. On the other hand, Jeffrey M. Smith, "Frankenstein Peas," *The Ecologist* (April 2006), reports on a study that genetically modified peas fed to mice caused serious immune system problems. Similar concerns are expressed by Artemis Dona and Ioannis S. Arvanitoyannis, "Health Risks of Genetically Modified Foods," *Critical Reviews in Food Science & Nutrition* (February 2009). See also Javier A. Magana-Gomez and Ana M. Calderon de la Barca, "Risk Assessment of Genetically Modified Crops for Nutrition and Health," *Nutrition Reviews* (January 2009).

The UN Food and Agriculture Organization's 2004 annual report, *The State of Food and Agriculture 2003–2004*, FAO Agriculture Series No. 35 (Rome, 2004), maintains that the biggest problem with genetically engineered crops is that the technology has focused so far on crops of interest to large commercial firms. GM crops have not spread fast enough to small farmers, although where they have been introduced into developing countries, they have yielded economic gains and reduced the use of toxic chemicals. The report concludes that there have been no adverse health or environmental consequences so far. Continued safety will require more research and governmental regulation and monitoring. Jerry Cayford notes in "Breeding Sanity into the GM Food Debate," *Issues in Science and Technology* (Winter 2004) that the issue is one of social justice as much as it is one of science. Who will control the world's food supply? Which philosophy—democratic competition or technocratic monopoly—will prevail? Theodoros H. Varzakas, et al., "The Politics and Science Behind GMO Acceptance," *Critical Reviews in Food Science & Nutrition* (June 2007), notes that in Europe a number of food scares (including Mad Cow disease) have alarmed consumers, and GMOs "despite the intense reactions from Non Governmental Organizations and consumer organizations have entered our lives with inadequate legislative measures to protect consumers from their consumption."

ISSUE 15

Can Organic Farming Feed the World?

YES: Catherine Badgley, et al., "Organic Agriculture and the Global Food Supply," *Renewable Agriculture & Food Systems* (June 2007)

NO: John J. Miller, from "The Organic Myth," *National Review* (February 9, 2004)

ISSUE SUMMARY

YES: Catherine Badgley, et al., argue that organic methods could produce enough food to sustain a global human population that is even larger than today's, and without requiring additional farmland. Organic agriculture would also decrease the undesirable environmental effects of conventional farming.

NO: John J. Miller argues that organic farming is not productive enough to feed today's population, much less larger future populations; it is prone to dangerous biological contamination; and it is not sustainable.

Introduction

There was a time when all farming was organic. Fertilizer was compost and manure. Fields were periodically left fallow (unfarmed) to recover soil moisture and nutrients. Crops were rotated to prevent nutrient exhaustion. Pesticides were nonexistent. And farmers were at the mercy of periodic droughts (despite irrigation) and insect infestations.

As the population grew, so did the demand for food. In Europe and America, the concomitant demand for fertilizer led in the nineteenth century to a booming trade in guano mined from Caribbean and Pacific islands where deposits of seabird dung could be a hundred and fifty feet thick. When the guano deposits were exhausted, there was an agricultural crisis that was relieved only by the invention of synthetic nitrogen-containing fertilizers early in the twentieth century. See Jimmy Skaggs, *The Great Guano Rush: Entrepreneurs and American Overseas Expansion* (St. Martin's, 1994), and G. J. Leigh, *The World's Greatest Fix: A History of Nitrogen and Agriculture* (Oxford, 2004). Unfortunately, synthetic fertilizers do not maintain the soil's content of organic

matter (humus). This deficit can be amended by tilling in sewage sludge, but the public is not usually very receptive to the idea, partly because of the "yuck factor," but also because sewage sludge may contain human pathogens and chemical contaminants.

Synthetic pesticides, beginning with DDT, came into use in the 1940s. Their history is nicely outlined in Keith S. Delaplane, *Pesticide Usage in the United States: History, Benefits, Risks, and Trends* (University of Georgia Extension Bulletin 1121). When they turned out to have problems—target species quickly became resistant, and when the chemicals reached human beings and wildlife on food and in water, they proved to be toxic—some people sought alternatives. These alternatives to synthetic fertilizers and pesticides (among other things) comprise what is usually meant by "organic farming." Proponents of organic farming have called it holistic, biodynamic, ecological, and natural and claimed a number of advantages for its practice. They say it both preserves the health of the soil and provides healthier food for people. They also argue that it should be used more, even to the point of replacing chemical-based "industrial" agriculture. Because proponents of chemicals hold that fertilizers and pesticides are essential to produce food in the quantities that a world population of nearly 7 billion people requires, and to hold food prices down to affordable levels, one strand of debate has been over whether organic agriculture can do the job.

In the following selections, University of Michigan professor Catherine Badgley, et al., argue that organic methods could produce enough food to sustain a global human population even larger than that of today, and without needing more farmland. Organic agriculture would also decrease the undesirable environmental effects of conventional farming. John J. Miller argues that organic farming is not productive enough to feed today's population, much less larger future populations; it is prone to dangerous biological contamination; and it is not sustainable. "Wishful thinking is at the heart of the organic-food movement."

YES

Catherine Badgley, et al.

Organic Agriculture and the Global Food Supply

Introduction

Ever since Malthus, the sufficiency of the global food supply to feed the human population has been challenged. One side of the current debate claims that green-revolution methods—involving high-yielding plant and animal varieties, mechanized tillage, synthetic fertilizers and biocides, and now transgenic crops—are essential in order to produce adequate food for the growing human population. Green-revolution agriculture has been a stunning technological achievement. Even with the doubling of the human population in the past 40 years, more than enough food has been produced to meet the caloric requirements for all of the world's people, if food were distributed more equitably. Yet Malthusian doubts remain about the future. Indeed, given the projection of 9 to 10 billion people by 2050 and the global trends of increased meat consumption and decreasing grain harvests per capita, advocates argue that a more intensified version of green-revolution agriculture represents our only hope of feeding the world. Another side of the debate notes that these methods of food production have incurred substantial direct and indirect costs and may represent a Faustian bargain. The environmental price of green-revolution agriculture includes increased soil erosion, surface and groundwater contamination, release of greenhouse gases, increased pest resistance, and loss of biodiversity. Advocates on this side argue that more sustainable methods of food production are essential over the long term.

If the latter view is correct, then we seem to be pursuing a short-term solution that jeopardizes long-term environmental sustainability. A central issue is the assertion that alternative forms of agriculture, such as organic methods, are incapable of producing as much food as intensive conventional methods do. A corollary is that organic agriculture requires more land to produce food than conventional agriculture does, thus offsetting any environmental benefits of organic production. Additionally, critics have argued that there is insufficient organically acceptable fertilizer to produce enough organic food without substantially increasing the land area devoted to agriculture.

Here, we evaluate the potential contribution of organic agriculture to the global food supply. Specifically, we investigate the principal objections against organic agriculture making a significant contribution—low yields and

From *Renewable Agriculture and Food Systems,* June 2007, pp. 86–108.

insufficient quantities of organic nitrogen fertilizers. The term 'organic' here refers to farming practices that may be called agroecological, sustainable, or ecological; utilize natural (non-synthetic) nutrient-cycling processes; exclude or rarely use synthetic pesticides; and sustain or regenerate soil quality. These practices may include cover crops, manures, compost, crop rotation, intercropping, and biological pest control. We are not referring to any particular certification criteria and include non-certified organic examples in our data.

Methods

We compiled data from the published literature about the current global food supply, comparative yields between organic and non-organic production methods, and biological nitrogen fixation by leguminous crops. These data were the basis for estimating the global food supply that could be grown by organic methods and the amount of nitrogen that could become available through increased use of cover crops as green manures.

Estimation of the Global Food Supply

Estimation of the global food supply grown by organic methods involved compiling data about current global food production, deriving ratios of the yields obtained from organic versus non-organic production methods, and applying these yield ratios to current global production values.

Global Food Production

Summary data from the Food and Agricultural Organization (FAO) for 2001 document the current global food supply—grown primarily by conventional methods in most of the developed world and primarily by low-intensive methods in most of the developing world. The FAO provides estimates of the current food supply in 20 general food categories which we modified for our study. We combined three pairs of categories (into sugars and sweeteners, vegetable oils and oil-crops, meat and offals). We omitted from consideration three categories (spices, stimulants, and "miscellaneous"), because they contribute few calories and little nutritional value to the daily diet and lack comparative data for organic versus non-organic production. In addition, we reported data for seafood and "other aquatic products" but did not estimate yield ratios for these categories, since most of these foods are currently harvested from the wild. Alcoholic beverages were reported since they contribute significantly to the average daily caloric intake, but no assessment of organic yields was made. The data presented for yield ratios pertain to ten categories covering the major plant and animal components of human diets.

Food-production data of the FAO include both commercial and domestic production and exclude losses during harvest. Pre-harvest crop losses are not included in the estimates; these losses may be substantial but are not necessarily more serious for organic production, since a host of methods is available for managing pests. For each country or region, the FAO data for the food supply available for human consumption take into account food production, exports, imports, and stocks, as well as losses of production to become livestock feed, seed, or waste. "Waste" refers to post-harvest loss during storage, transport, and processing. We compiled this information for the world, for developed countries, and for developing countries, following the FAO classification of countries as developed or developing.

Deriving Yield Ratios

We estimated the global organic food supply by multiplying the amount of food in the current (2001) food supply by a ratio comparing average organic: non-organic yields. Comparisons of organic to non-organic production are available for many plant foods and a few animal foods. For each of 293 comparisons of organic or semi-organic production to locally prevalent methods under field conditions, the yield ratio is the ratio of organic : non-organic production. A ratio of 0.96, for example, signifies that the organic yield is 96% that of the conventional yield for the same crop. The comparisons include 160 cases with conventional methods and 133 cases with low-intensive methods. Most examples are from the peer-reviewed, published literature; a minority come from conference proceedings, technical reports, or the Web site of an agricultural research station. Like Stanhill's 1990 survey of organic and conventional production, our data include numerous comparisons from paired farms and controlled experiments at research stations. The studies range in observation length from a single growing season to over 20 years. Despite the observation that yields following conversion from conventional to organic production initially decline and then may increase with time, we included studies regardless of duration. All of Stanhill's examples (which are included here) were from the developed world, whereas our dataset also includes diverse examples from the developing world. No attempt was made to bias the results in favor of organic yields; many examples from developed and developing countries exhibit low comparative yields. We avoided generalizations based on countrywide or regional average yields by organic or conventional methods. Some examples are based on yields before and after conversion to organic methods on the same farm.

We grouped examples into ten general food categories and determined the average yield ratio for all cases in each food category. . . . If no data were available (e.g., tree nuts) for estimating global organic production, then we used the average yield ratio for all plant foods, or all animal foods where relevant. For individual studies in which several yield ratios were reported for a single crop (e.g., 0.80–2.00) grown under the same treatment, we took the average as the value for the study. When different treatments were described, we listed a value for each treatment. Averaging the yield ratios across each general food category reduced the effects of unusually high or low yield ratios from individual studies. As these studies come from many regions in developed and developing countries, the average yield ratios are based on a broad range of soils and climates. The average yield ratio is not intended as a predictor of the yield difference for a specific crop or region but as a general indicator of the potential yield performance of organic relative to other methods of production.

Studies in the global south usually demonstrate increases in yields following conversion to organic methods, but these studies are not comparable with those in the developed world. At present, agriculture in developing countries is generally less intensive than in the developed world. Organic production is often compared with local, resource-poor methods of subsistence farming, which may exhibit low yields because of limited access by farmers to natural resources, purchased inputs, or extension services. While adoption of green-revolution methods has typically increased yields, so has intensification by organic methods. Such methods more often result in non-certified than in certified organic production, since most food produced is for local consumption where certification is not at issue. Data from these studies are relevant for our inquiry, which seeks quantitative comparisons between organic production and prior methods, whether by conventional or subsistence practices, since both prevailing methods contribute to global food production.

Estimating the Global Food Supply

Using the average yield ratio for each food category, we estimated the amount of food that could be grown organically by multiplying the amount of food currently produced times the average yield ratio. Following the FAO methodology, this estimate was then proportionally reduced for imports, exports, and losses to give the estimated organic food supply after losses, which is the food supply available for human consumption. We assumed that all food currently produced is grown by non-organic methods, as the global area of certified organic agriculture is only 0.3%.

We constructed two models of global food production grown by organic methods. Model 1 applied the organic : non-organic (conventional) yield ratios derived from studies in developed countries to the entire agricultural land base. This model effectively assumes that, if converted to organic production, the low-intensity agriculture present in much of the developing world would have the same or a slight reduction in yields that has been reported for the developed world, where green-revolution methods now dominate. Model 2 applied the yield ratios derived from studies in the developed world to food production in the developed world, and the yield ratios derived from studies in the developing world to food production in the developing world. The sum of these separate estimates provides the global estimate. . . .

Additional Model Assumptions

Both models were based on the pattern of food production and the amount of land devoted to crops and pasture in 2001. The models estimate the kinds and relative amounts of food that are currently produced and consumed, including the same pattern of total and per-capita consumption of meat, sugars, and alcoholic beverages. Additional assumptions include (1) the same proportion of foods grown for animal feed (e.g., 36% of global grain production), (2) the same proportion of food wasted (e.g., 10% of starchy roots), and (3) the same nutritional value of food (e.g., for protein and fat content in each food category), even though changes in some of these practices would benefit human or environmental health. Finally, we made no assumptions about food distribution and availability, even though changes in accessibility are necessary to achieve global food security. These assumptions establish the boundary conditions for the models but are not intended as an assessment of the sustainability of the current global food system.

Calories per Capita

The calories per capita resulting from Models 1 and 2 were estimated by multiplying the average yield ratios (organic : non-organic) in each food category by the FAO estimate of per-capita calories currently available in that food category.

Nitrogen Availability with Cover Crops

The main limiting macronutrient for agricultural production is biologically available nitrogen (N) in most areas, with phosphorus limiting in certain tropical regions. For phosphorus and potassium, the raw materials for fertility in organic and conventional systems come largely from mineral sources and are not analyzed here.

Nitrogen amendments in organic farming derive from crop residues, animal manures, compost, and biologically fixed N from leguminous plants. A common practice in temperate regions is to grow a leguminous cover crop during the winter fallow period, between food crops, or as a relay crop during the growing season. Such crops are called green manures when they are not harvested but plowed back into the soil for the benefit of the subsequent crop. In tropical regions, leguminous cover crops can be grown between plantings of other crops and may fix substantial amounts of N in just 46–60 days. To estimate the amount of N that is potentially available for organic production, we considered only what could be derived from leguminous green manures grown between normal cropping periods. Nitrogen already derived from animal manure, compost, grain legume crops, or other methods was excluded from the calculations, as we assumed no change in their use. The global estimate of N availability was determined from the rates of N availability or N-fertilizer equivalency reported in 77 studies—33 for temperate regions and 44 for tropical regions, including three studies from arid regions and 18 studies of paddy rice. N availability values in kg ha^{-1} were obtained from studies as either 'fertilizer replacement value,' determined as the amount of N fertilizer needed to achieve equivalent yields to those obtained using N from cover crops, or calculated as 66% of N fixed by a cover crop becoming available for plant uptake during the growing season following the cover crop. . . . We estimated the total amount of N available for plant uptake by multiplying the area currently in crop production (but not already in leguminous forage production—large-scale plantings of perennial legume systems) by the average amount (kg ha^{-1}) of N available to the subsequent crop from leguminous crops during winter fallow or between crops.

Results and Discussion

Estimates of Food and Caloric Production under Organic Agriculture

. . . According to Model 1, the estimated organic food supply is similar in magnitude to the current food supply for most food categories (grains, sweeteners, tree nuts, oil crops and vegetable oils, fruits, meat, animal fats, milk, and eggs). This similarity occurs because the average yield ratios for these categories range from 0.93 to 1.06. For other food categories (starchy roots, legumes, and vegetables), the average yield ratios range from 0.82 to 0.89, resulting in somewhat lower production levels. The average yield ratio for all 160 examples from developed countries is 0.92, close to Stanhill's average relative yield of 0.91. According to Model 2, the estimated organic food supply exceeds the current food supply in all food categories, with most estimates over 50% greater than the amount of food currently produced. The higher estimates in Model 2 result from the high average yield ratios of organic versus current methods of production in the developing world. The average yield ratio for the 133 examples from the developing world is 1.80. We consider Model 2 more realistic because it uses average yield ratios specific to each region of the world. These two models likely bracket the best estimate of global organic food production. Model 1 may underestimate the potential yield ratios of organic to conventional production, since many agricultural soils in developed countries have been degraded by years of tillage, synthetic fertilizers, and pesticide residues. Conversion to organic methods on such soils typically results in an initial decrease in yields, relative to conventional methods, followed by an increase in yields as soil quality is restored. Model 2 may overestimate the yield ratios for the developing world to the extent that green-revolution methods are practiced.

Both models suggest that organic methods could sustain the current human population, in terms of daily caloric intake. The current world food supply after losses provides 2786 kcal person day. The average caloric requirement for a healthy adult is between 2200 and 2500 kcal day^{-1}. Model 1 yielded 2641 kcal $person^{-1}$ day^{-1}, which is above the recommended value, even if slightly less than the current availability of calories. Model 2 yielded 4381 kcal $person^{-1}$ day^{-1}, which is 57% greater than current availability. This estimate suggests that organic production has the potential to support a substantially larger human population than currently exists. Significantly, both models have high yields of grains, which constitute the major caloric component of the human diet. Under Model 1, the grain yield is 93% that of current production. Under Model 2, the grain yield is 145% that of current production.

The most unexpected aspect of this study is the consistently high yield ratios from the developing world. These high yields are obtained when farmers incorporate intensive agroecological techniques, such as crop rotation, cover cropping, agroforestry, addition of organic fertilizers, or more efficient water management. In some instances, organic-intensive methods resulted in higher yields than conventional methods for the same crop in the same setting (e.g., the system of rice intensification (SRI) in ten developing countries). Critics have argued that some of these examples exceed the intrinsic yield limits set by crop genetics and the environmental context. (Such controversy surrounds the 'SRI' and our data include studies from both sides of this controversy.) Yet alternative agricultural methods may elicit a different pathway of gene expression than conventional methods do. Thus, yield limits for conventionally grown crops may not predict the yield limits under alternative methods.

Crop Rotation and Yield-time Adjustment

Organic grain production frequently uses a different rotation system than conventional production. For example, it is common in organic systems to have a three or four-year rotation (with legumes or other crops) for corn, while the conventional rotation often involves planting corn every other year. In situations like this, it is difficult to make yield comparisons between organic and conventional systems without some sort of time adjustment. Although the high variation among rotation systems worldwide makes it impossible to provide a general time–yield adjustment, evaluating potential differences in performance is important. A thorough evaluation of the rotation effect requires knowledge of the plot-to-plot yield differences between organic and conventional production and the rate of decline of both organic and conventional production as a function of the rotation sequence—information that has not yet been experimentally demonstrated. While rotations would undoubtedly differ under a global organic production system, we have no basis for concluding that this system would be unable to provide enough grain to feed the world.

Organic Nitrogen Fertilizer

In 2001, the global use of synthetic N fertilizers was 82 million Mg (metric ton). Our global estimate of N fixed by the use of additional leguminous crops as fertilizer is 140 million Mg, which is 58 million Mg greater than the amount of synthetic N currently in use. Even in the US, where substantial amounts of synthetic N are used in agriculture, the estimate shows a surplus of available N through the additional use of leguminous cover crops between normal cropping periods. The global estimate is based on an average N availability or N-fertilizer equivalency of 102.8 kg N ha^{-1}. For temperate regions, the average is 95.1 kg Nha^{-1} and for tropical regions, the average is 108.6 kg N ha^{-1}. These rates of biological N fixation and release can match N availability with crop uptake and achieve yields equivalent to those of high-yielding conventionally grown crops. In temperate regions, winter cover crops grow well in fall after harvest and in early spring before planting of the main food crop. Research at the Rodale Institute (Pennsylvania, USA) showed that red clover and hairy vetch as winter covers in an oat/wheat–corn–soybean rotation with no additional fertilizer inputs achieved yields comparable to those in conventional controls. Even in arid and semi-arid tropical regions, where water is limiting between periods of crop production, drought-resistant green manures, such as pigeon peas or groundnuts, can be used to fix N. Use of cover crops in

arid regions has been shown to increase soil moisture retention, and management of dry season fallows commonly practiced in dry African savannas can be improved with the use of N-fixing cover crops for both N-fixation and weed control. Areas in sub-Saharan Africa which currently use only very small amounts of N fertilizer (9 kg ha^{-1}, much of it on non-food crops) could easily fix more N with the use of green manures, leading to an increase in N availability and yields in these areas. In some agricultural systems, leguminous cover crops not only contribute to soil fertility but also delay leaf senescence and reduce the vulnerability of plants to disease.

Our estimates of N availability from leguminous cover crops do not include other practices for increasing biologically fixed N, such as intercropping, alley cropping with leguminous trees, rotation of livestock with annual crops, and inoculation of soil with free-living N-fixers—practices that may add considerable N fertility to plant and animal production. In addition, rotation of food-crop legumes, such as pulses, soy, or groundnuts, with grains can contribute as much as 75 kg N ha^{-1} to the grains that follow the legumes.

These methods can increase the N-use efficiency by plants. Since biologically available N is readily leached from soil or volatilized if not taken up quickly by plants, N use in agricultural systems can be as low as 50%. Organic N sources occur in more stable forms in carbon-based compounds, which build soil organic matter and increase the amount of N held in the soil. Consequently, the amount of N that must be added each year to maintain yields may actually decrease, because the release of organic N fixed in one season occurs over several years.

These results imply that, in principle, no additional land area is required to obtain enough biologically available N to replace the current use of synthetic N fertilizers. Although this scenario of biological N fixation is simple, it provides an assessment, based on available data, for one method of organic N-fertility production that is widely used by organic farmers and is fairly easy to implement on a large scale. This scenario is not intended to be prescriptive for any particular rotation or location, but to demonstrate the possibility of this type of cover-cropping system to fix large quantities of N without displacing food crops or expanding land area. The Farm Systems Trial at the Rodale Institute uses legume cover crops grown between main crops every third year as the only source of N fertility and reports comparable grain yields to those of conventionally managed systems, while using non-legume winter cover crops in other years to maintain soil quality and fertility and to suppress weeds. In practice, a range of methods acceptable in organic agriculture provides critical flexibility in N-management, including many sources other than cover crops. Although some environmental and economic circumstances pose challenges to reliance on leguminous fertilizers, the full potential of leguminous cover crops in agriculture is yet to be utilized. Implementation of existing knowledge could increase the use of green manures in many regions of the world. Future selection for crop varieties and green manures that have higher rates of N fixation, especially in arid or semi-arid regions, and perform well under N-limiting conditions, as well as for improved strains of N-fixing symbionts, combined with reductions in the amount of N lost from legume-based production systems, and increases in the planting of legumes, hold great promise for increasing the role of biological N-fixation in fertility management. The capacity for increased reliance on legume fertilizers would be even greater with substantive changes in the food system, such as reduction of food waste and feeding less grain to livestock.

Prospects for More Sustainable Food Production

Our results suggest that organic methods of food production can contribute substantially to feeding the current and future human population on the current agricultural land base, while maintaining soil fertility. In fact, the models suggest the possibility that the agricultural land base could eventually be reduced if organic production methods were employed, although additional intensification via conventional methods in the tropics would have the same effect. Our calculations probably underestimate actual output on many organic farms. Yield ratios were reported for individual crops, but many organic farmers use polycultures and multiple cropping systems, from which the total production per unit area is often substantially higher than for single crops. Also, there is scope for increased production on organic farms, since most agricultural research of the past 50 years has focused on conventional methods. Arguably, comparable efforts focused on organic practices would lead to further improvements in yields as well as in soil fertility and pest management. Production per unit area is greater on small farms than on large farms in both developed and developing countries; thus, an increase in the number of small farms would also enhance food production. Finally, organic production on average requires more hand labor than does conventional production, but the labor is often spread out more evenly over the growing season. This requirement has the potential to alleviate rural unemployment in many areas and to reduce the trend of shantytown construction surrounding many large cities of the developing world.

The Millennium Ecosystem Assessment recommends the promotion of agricultural methods that increase food production without harmful tradeoffs from excessive use of water, nutrients, or pesticides. Our models demonstrate that organic agriculture can contribute substantially to a more sustainable system of food production. They suggest not only that organic agriculture, properly intensified, could produce much of the world's food, but also that developing countries could increase their food security with organic agriculture. The results are not, however, intended as forecasts of instantaneous local or global production after conversion to organic methods. Neither do we claim that yields by organic methods are routinely higher than yields from green-revolution methods. Rather, the results show the potential for serious alternatives to green-revolution agriculture as the dominant mode of food production.

In spite of our optimistic prognosis for organic agriculture, we recognize that the transition to and practice of organic agriculture contain numerous challenges—agronomically, economically, and educationally. The practice of organic agriculture on a large scale requires support from research institutions dedicated to agroecological methods of fertility and pest management, a

strong extension system, and a committed public. But it is time to put to rest the debate about whether or not organic agriculture can make a substantial contribution to the food supply. It can, both locally and globally. The debate should shift to how to allocate more resources for research on agroecological methods of food production and how to enhance the incentives for farmers and consumers to engage in a more sustainable production system. Finally, production methods are but one component of a sustainable food system. The economic viability of farming methods, land tenure for farmers, accessibility of markets, availability of water, trends in food consumption, and alleviation of poverty are essential to the assessment and promotion of a sustainable food system.

John J. Miller

NO

The Organic Myth: A Food Movement Makes a Pest of Itself

Somewhere in the cornfields of Britain, a hungry insect settled on a tall green stalk and decided to have a feast. It chewed into a single kernel of corn, filled its little belly, and buzzed off—leaving behind a tiny hole that was big enough to invite a slow decay. The agent of the decomposition was a fungus known to biologists as *Fusarium*. Farmers have a much simpler name for it: corn ear rot.

As the mold spread inside the corn, it left behind a cancer causing residue called fumonisin. This sequence repeated itself thousands and thousands of times until the infested corn was harvested and sold last year as Fresh and Wild Organic Maize Meal, Infinity Foods Organic Maize Meal, and several other products.

Consuming trace amounts of fumonisin is harmless, but large doses can be deadly. Last fall, the United Kingdom's Food Standards Agency detected alarming concentrations of the toxin in all six brands of organic corn meal subjected to testing—for a failure rate of 100 percent. The average level of contamination was almost 20 times higher than the safety threshold Europeans have set for fumonisin. The tainted products were immediately recalled from the food chain. In contrast, inspectors determined that 20 of the 24 non-organic corn meal products they examined were unquestionably safe to eat.

Despite this, millions of people continue to assume that organic foods are healthier than non-organic ones, presumably because they grow in pristine settings free from icky chemicals and creepy biotechnology. This has given birth to an energetic political movement. In 2002, activists in Oregon sponsored a ballot initiative that essentially would have required the state to slap biohazard labels on anything that wasn't produced in ways deemed fit by anti-biotech agitators. Voters rejected it, but the cause continues to percolate. Hawaiian legislators are giving serious thought to banning biotech crop tests in their state. In March, California's Mendocino County may outlaw biotech plantings altogether.

Beneath it all lurks the belief that organic food is somehow better for us. In one poll, two-thirds of Americans said that organic food is healthier. But they're wrong: It's no more nutritious than food fueled by industrial fertilizers, sprayed with synthetic pesticides, and genetically altered in science labs. And the problem isn't limited to the fungal infections that recently cursed organic

From *The National Review,* February 9, 2004, pp. 35–37.

corn meal in Britain; bacteria are a major source of disease in organic food as well. To complicate matters further, organic farming is incredibly inefficient. If its appeal ever grew beyond the boutique, it would pose serious threats to the environment. Consumers who go shopping for products emblazoned with the USDA's "organic" seal of approval aren't really helping themselves or the planet—and they're arguably hurting both.

No Fear

Here's the good news: At no point in human history has food been safer than it is today, despite occasional furors like the recent one over an isolated case of mad-cow disease here in the U.S. People still get sick from food—each year, about 76 million Americans pick up at least a mild illness from what they put in their mouths—but modern agricultural methods have sanitized our fare to the point where we may eat without fear. This is true for all food, organic or otherwise.

And that raises a semantic question: What is it about organic food that makes it "organic"? The food we think of as nonorganic isn't really *in*organic, as if it were composed of rocks and minerals. In truth, everything we eat is organic—it's just not "organic" the way the organic-food movement has come to define the word.

About a decade ago, the federal government decided to wade into this semantic swamp. There was no compelling reason for this, but Congress nonetheless called for the invention of a National Organic Rule. It became official in 2002. Organic food, said the bureaucrats, is produced without synthetic fertilizers, conventional pesticides, growth hormones, genetic engineering, or germ-killing radiation. There are also varying levels of organic-ness: Special labels are available for products that are "made with organic ingredients" (which means the food is 70 percent organic), "organic" (which means 95 percent organic), and "100 percent organic." It's not at all clear what consumers are supposed to do with this information. As the Department of Agriculture explains on its website, the "USDA makes no claims that organically produced food is safer or more nutritious than conventionally produced food."

It doesn't because it can't: There's no scientific evidence whatsoever showing that organic food is healthier. So why bother with a National Organic Rule? When the thing was in development, the Clinton administration's secretary of agriculture, Dan Glickman, offered an answer: "The organic label is a marketing tool. It is not a statement about food safety." In other words, those USDA labels are intended to give people warm fuzzies for buying pricey food.

And herein lies one of the dirty secrets of organic farming: It's big business. Although the organic movement has humble origins, today most of its food isn't produced on family farms in quaint villages or even on hippie communes in Vermont. Instead, the industry has come to be dominated by large corporations that are normally the dreaded bogeymen in the minds of many organic consumers. A single company currently controls about 70 percent of the market in organic milk. California grows about $400 million per year in organic produce—and about half of it comes from just five farms. The

The alternative is to chop down rainforests so that we may dine on organic soybeans.

There's one more important reason that organics can't feed the world: There just isn't enough cow poop to go around. For fun, pretend that U.N. secretary-general Kofi Annan chowed on some ergot rye, decreed that all of humanity must eat nothing but organic food, and that all of humanity responded by saying, "What the heck, we'll give it a try." Forget about the population boom ahead. The immediate problem would be generating enough manure to fertilize all the brand-new, low-yield organic crop fields. There are a little more than a billion cattle in the world today, and each bovine needs between 3 and 30 acres to support it. Conservative estimates say it would take around 7 or 8 billion cattle to produce sufficient heaps of manure to sustain our all-organic diets. The United States alone would need about a billion head (or rear, to be precise). The country would be made up of nothing but cities and manure fields—and the experiment would give a whole new meaning to the term "fruited plains."

This is the sort of future the organic-food movement envisions—and its most fanatical advocates aren't planning to win any arguments on the merits or any consumers on the quality of organic food. In December, when a single U.S. animal was diagnosed with mad-cow disease, nobody was more pleased than Ronnie Cummins of the Organic Consumers Association, who has openly hoped for a public scare that would spark a "crisis of confidence" in American food. No such thing happened, but Cummins should be careful about what he wishes for: Germany's first case of mad-cow disease surfaced at a slaughterhouse that specializes in organic beef.

But then wishful thinking is at the heart of the organic-food movement. Its whole market rationale depends on the misperception that organic foods are somehow healthier for both consumers and Mother Earth. Just remember: Nature's Valley can't be found on any map. It's a state of mind.

POSTSCRIPT

Can Organic Farming Feed the World?

It is worth noting that Alex Avery, author of *The Truth about Organic Foods* (Henderson, 2006) and director of research and education for the Hudson Institute's Center for Global Food Issues, argues in "'Organic Abundance' Report: Fatally Flawed," Center for Global Food Issues, Hudson Institute (September 2007), that Badgley, et al., are guilty of misreporting data, inflating averages by counting high organic yields multiple times, and counting as organic farming clearly nonorganic methods.

Quantitative yield comparisons are not the only organic-related topics that prompt debate. Is organic food better or safer for the consumer than non-organic food? Faidon Magkos, et al., "Organic Food: Buying More Safety or Just Peace of Mind? A Critical Review of the Literature," *Critical Reviews in Food Science & Nutrition* (January 2006), report that the quality and safety of organic food are largely a matter of perception. "Relevant scientific evidence . . . is scarce, while anecdotal reports abound." Pesticide and herbicide residues may be lower, but even on non-organic food they are low. Environmental contaminants are likely to affect both organic and non-organic foods. "'Organic' does not automatically equal 'safe.'"

Is organic farming better for the environment? Soil fertility is in decline in many parts of the world; see Alfred E. Herteminck, "Assessing Soil Fertility Decline in the Tropics Using Soil Chemical Data," *Advances in Agronomy* (2006). In Africa, the situation is extraordinarily serious. According to the International Center for Soil Fertility and Agricultural Development (http://www.ifdc.org/New_Design/Whats_New/africasfailingagriculture033006.pdf), "About 75 percent of the farmland in sub-Saharan Africa is plagued by severe degradation, losing basic soil nutrients needed to grow the crops that feed Africa, according to a new report . . . on the precipitous decline in African soil health from 1980 to 2004. Africa's crisis in food production and battle with hunger are largely rooted in this 'soil health crisis.'" Proponents of organic farming argue that organic methods are essential to relieving the crisis, but one study of changes in soil fertility, as indicated by crop yield, earthworm numbers, and soil properties, after converting from conventional to organic practices, found that different soils responded differently, with some improving and some not; see Anne Kjersti Bakken, et al., "Soil Fertility in Three Cropping Systems after Conversion from Conventional to Organic Farming," *Acta Agriculturae Scandinavica: Section B, Soil & Plant Science* (June 2006). Richard Wood, et al., "A Comparative Study of Some Environmental Impacts of Conventional and Organic Farming in Australia," *Agricultural Systems* (September 2006), find in a comparison of organic and conventional farms "that direct energy use, energy related emissions, and greenhouse gas emissions are higher for the" former.

Paul Collier, "The Politics of Hunger," *Foreign Affairs* (November/December 2008), says that part of the problem is "the middle- and upper-class love affair with peasant [organic] agriculture." What the world needs is more commercial agriculture and more science, as well as an end to subsidies for biofuels production. According to Catherine M. Cooney, "Sustainable Agriculture Delivers the Crops," *Environmental Science & Technology* (February 15, 2006), "Sustainable agriculture, such as crop rotation, organic farming, and genetically modified seeds, increased crop yields by an average of 79 percent" while also improving the lives of farmers in developing countries. Cong Tu, et al., "Responses of Soil Microbial Biomass and N Availability to Transition Strategies from Conventional to Organic Farming Systems," *Agriculture, Ecosystems & Environment* (April 2006), note that a serious barrier to changing from conventional to organic farming, despite soil improvements, is an initial reduction in yield and increase in pests. David Pimentel, et al., "Environmental, Energetic, and Economic Comparisons of Organic and Conventional Farming Systems," *Bioscience* (July 2005), find that organic farming uses less energy, improves soil, and has yields comparable to those of conventional farming but crops probably cannot be grown as often (because of fallowing), which thus reduces long-term yields. However, "because organic foods frequently bring higher prices in the marketplace, the net economic return per [hectare] is often equal to or higher than that of conventionally produced crops." This is one of the factors that prompts Craig J. Pearson to argue in favor of shifting "from conventional open or leaky systems to more closed, regenerative systems" in "Regenerative, Semiclosed Systems: A Priority for Twenty-First-Century Agriculture," *Bioscience* (May 2007).

Better economic return means that organic farming is currently good for the organic farmer. However, the advantage would disappear if the world converted to organic farming. Initial declines in yield mean the conversion would be difficult, but the longer we wait and the more population grows, the more difficult it will be. Whether the conversion is essential depends on the availability of alternative solutions to the problem, and it is worth noting that high energy prices make chemical fertilizers increasingly expensive. Sadly, Stacey Irwin, "Battle High Fertilizer Costs," *Farm Industry News* (January 2006), does not mention the possibility of using organic methods.