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# 9

# *Feeding Eight Billion Well*

In April 2005, the World Food Programme and the Chinese government jointly announced that food aid shipments to China would stop at the end of the year. For a country where a generation ago hundreds of millions of people were chronically hungry, this was a landmark achievement. Not only has China ended its dependence on food aid, but almost overnight it has become the world's third largest food aid donor.[1]

The key to China's success was the economic reforms in 1978 that dismantled its system of agricultural collectives, known as production teams, and replaced them with family farms. In each village, the land was allocated among families, giving them long-term leases on their piece of land. The move harnessed the energy and ingenuity of China's rural population, raising the grain harvest by half from 1977 to 1986. With its fast-expanding economy raising incomes, with population growth slowing, and with the grain harvest climbing, China eradicated most of its hunger in less than a decade—in fact, it eradicated more hunger in a shorter period of time than any country in history.[2]

While hunger has been disappearing in China, it has been spreading in sub-Saharan Africa and parts of the Indian subcontinent. As a result, the number of people in developing countries who are hungry has increased from a recent historical low of 800 million in 1996 to 830 million in 2003. In the absence of strong leadership, the record or near-record grain prices in late 2007 will likely raise the number of hungry people even further, with children suffering the most.[3]

One key to the threefold expansion in the world grain harvest since 1950 was the rapid adoption in developing countries of high-yielding wheats and rices originally developed in Japan and hybrid corn from the United States. The spread of these highly productive seeds, combined with a tripling of irrigated area and an 11-fold increase in world fertilizer use, tripled the world grain harvest. Growth in irrigation and fertilizer use essentially removed soil moisture and nutrient constraints on much of the world's cropland.[4]

Now the outlook is changing. Farmers are faced with shrinking supplies of irrigation water, a diminishing response to additional fertilizer use, rising temperatures, the loss of cropland to nonfarm uses, rising fuel costs, and a dwindling backlog of yield-raising technologies.

At the same time, they also face a fast-growing demand for farm products from the annual addition of some 70 million people a year, the desire of some 5 billion people to consume more livestock products, and the millions of motorists turning to crop-based fuels to supplement tightening supplies of gasoline and diesel fuel.[5]

This helps explain why world grain production has fallen short of consumption in seven of the last eight years, dropping world grain stocks to the lowest level since 1974. Farmers and agronomists are now being thoroughly challenged.[6]

## Rethinking Land Productivity

The shrinking backlog of unused agricultural technology and the associated loss of momentum in raising cropland productivity is found worldwide. Between 1950 and 1990, world grain yield per hectare climbed by 2.1 percent a year, ensuring rapid growth in the world grain harvest. From 1990 to 2007, however, it rose only 1.2 percent annually. This is partly because the yield response to the additional application of fertilizer is diminishing and partly because irrigation water supplies are limited.[7]



This calls for fresh thinking on how to raise cropland productivity. One way is to breed crops that are more tolerant of drought and cold. U.S. corn breeders have developed corn varieties that are more drought-tolerant, enabling corn production to move westward into Kansas, Nebraska, and South Dakota. Kansas, the leading U.S. wheat-producing state, has used a combination of drought-resistant varieties in some areas and irrigation in others to expand corn planting to where the state now produces more corn than wheat. Similarly, corn production is expanding in more northern states such as North Dakota and Minnesota.[8]

Another way of raising land productivity, where soil moisture permits, is to increase the area of multicropped land that produces more than one crop per year. Indeed, the tripling in the world grain harvest since 1950 is due in part to impressive increases in multiple cropping in Asia. Some of the more common combinations are wheat and corn in northern China, wheat and rice in northern India, and the double or triple cropping of rice in southern China, southern India, and rice-growing countries in Southeast Asia.[9]

The spread in double cropping of winter wheat and corn on the North China Plain helped boost China's grain production to where it rivaled that of the United States. Winter wheat grown there yields close to 4 tons per hectare. Corn averages 5 tons. Together these two crops, grown in rotation, can yield 9 tons per hectare per year. China's double cropped rice yields 8 tons per hectare.[10]

Forty years ago, North India produced only wheat, but with the advent of the earlier maturing high-yielding wheats and rices, wheat could be harvested in time to plant rice. This wheat/rice combination is now widely used throughout the Punjab, Haryana, and parts of Uttar Pradesh. The wheat yield of 3 tons and rice yield of 2 tons combine for 5 tons of grain per hectare, helping to feed India's 1.2 billion people.[11]

In North America and Western Europe, which in the past have restricted cropped area to control surpluses, there is some potential for double cropping that has not been fully exploited. In the United States, the lifting of planting area restrictions in 1996 opened new opportunities for multiple cropping. The most common U.S. double cropping combination is winter wheat with soybeans as a summer crop. Since soybeans fix nitrogen, this reduces the need to apply fertilizer to wheat.[12]

A concerted U.S. effort to both breed earlier maturing varieties and develop cultural practices that would facilitate multiple cropping could substantially boost crop output. If China's farmers can extensively double crop wheat and corn, then U.S. farmers—at a similar latitude and with similar climate patterns—could do the same if agricultural research and farm policy were reoriented to support it.

Western Europe, with its mild winters and high-yielding winter wheat, might also be able to double crop more with a summer grain, such as corn, or with a winter oilseed crop. Elsewhere, Brazil and Argentina have an extended frost-free growing season that supports extensive multicropping, often wheat or corn with soybeans.[13]

In many countries, including the United States, most of those in Western Europe, and Japan, fertilizer use has reached a level where using more has little effect on crop yields. There are still some places, however, such as most of Africa, where additional fertilizer would help boost yields. Unfortunately, sub-Saharan Africa lacks the infrastructure to transport fertilizer economically to the villages where it is needed. As a result of nutrient depletion, grain yields in much of sub-Saharan Africa are stagnating.[14]

One encouraging response to this situation in Africa is the simultaneous planting of grain and leguminous trees. At first the trees grow slowly, permitting the grain crop to mature and be harvested; then the saplings grow quickly to several feet in height, dropping leaves that provide nitrogen and organic matter, both sorely needed in African soils. The wood is then cut and used for fuel. This simple, locally adapted technology, developed by scientists at the International Centre for Research in Agroforestry in Nairobi, has enabled farmers to double their grain yields within a matter of years as soil fertility builds.[15]

Another often overlooked issue is the effect of land tenure on productivity. In China, this issue was addressed in March 2007 when the National People's Congress passed legislation protecting property rights. Farmers who had previously occupied their land under 30-year leases would gain additional protection from land confiscation by local officials who, over a number of years, had seized land from some 40 million farmers, often for development. Secure land ownership encourages farmers to



invest in and improve their land. A Rural Development Institute survey in China revealed that farmers with documentation of land rights were twice as likely to make long-term investments in their land, such as adding greenhouses, orchards, or fishponds.[16]

Despite local advances, the overall loss of momentum in expanding food production is unmistakable. It will force us to think more seriously about stabilizing population, moving down the food chain, and using the existing harvest more productively. Achieving an acceptable worldwide balance between food and people may now depend on stabilizing population as soon as possible, reducing the unhealthily high consumption of animal products among the affluent, and restricting the conversion of food crops to automotive fuels.

## Raising Water Productivity

With water shortages emerging as a constraint on food production growth, the world needs an effort to raise water productivity similar to the one that nearly tripled land productivity during the last half of the twentieth century. Land productivity is typically measured in tons of grain per hectare or bushels per acre. A comparable indicator for irrigation water is kilograms of grain produced per ton of water. Worldwide, that average is now roughly 1 kilogram of grain per ton of water used.[17]

Since it takes 1,000 tons of water to produce 1 ton of grain, it is not surprising that 70 percent of world water use is devoted to irrigation. Thus, raising irrigation efficiency is central to raising water productivity overall. Using more water-efficient irrigation technologies and shifting to crops that use less water permit the expansion of irrigated area even with a fixed water supply. Eliminating water and energy subsidies that encourage wasteful water use allows water prices to rise to market levels. Higher water prices encourage all water users to use water more efficiently. Institutionally, local rural water users associations that directly involve those using the water in its management have raised water productivity in many countries.[18]

Data on water irrigation efficiency for surface water projects—that is, dams that deliver water to farmers through a network of canals—show that crop usage of irrigation water never reaches 100 percent simply because some irrigation water evaporates, some percolates downward, and some runs off. Water policy analysts Sandra Postel and Amy Vickers found that "surface water irrigation efficiency ranges between 25 and 40 percent in India, Mexico, Pakistan, the Philippines, and Thailand; between 40 and 45 percent in Malaysia and Morocco; and between 50 and 60 percent in Israel, Japan, and Taiwan." Irrigation water efficiency is affected not only by the type and condition of irrigation systems but also by soil type, temperature, and humidity. In hot arid regions, the evaporation of irrigation water is far higher than in cooler humid regions.[19]

In a May 2004 meeting, China's Minister of Water Resources Wang Shucheng outlined for me in some detail the plans to raise China's irrigation efficiency from 43 percent in 2000 to 51 percent in 2010 and then to 55 percent in 2030. The steps he described included raising the price of water, providing incentives for adopting more irrigation-efficient technologies, and developing the local institutions to manage this process. Reaching these goals, he felt, would assure China's future food security.[20]

Raising irrigation water efficiency typically means shifting from the less efficient flood or furrow system to overhead sprinklers or drip irrigation, the gold standard of irrigation efficiency. Switching from flood or furrow to low-pressure sprinkler systems reduces water use by an estimated 30 percent, while switching to drip irrigation typically cuts water use in half.[21]

As an alternative to furrow irrigation, a drip system also raises yields because it provides a steady supply of water with minimal losses to evaporation. Since drip systems are both labor-intensive and water-efficient, they are well suited to countries with a surplus of labor and a shortage of water.[22]

A few small countries—Cyprus, Israel, and Jordan—rely heavily on drip irrigation. Among the big three agricultural producers, this more-efficient technology is used on 1–3 percent of irrigated land in India and China and on roughly 4 percent in the United States.[23]

In recent years, small-scale drip-irrigation systems—virtually a bucket with flexible plastic tubing to distribute the water—have been developed to irrigate small vegetable gardens with roughly 100 plants (covering 25 square meters). Somewhat larger drum systems irrigate 125 square meters. In both cases, the containers are elevated slightly, so that gravity distributes the



water. Large-scale drip systems using plastic lines that can be moved easily are also becoming popular. These simple systems can pay for themselves in one year. By simultaneously reducing water costs and raising yields, they can dramatically raise incomes of smallholders.[24]

Sandra Postel estimates that the combination of these drip technologies at various scales has the potential to profitably irrigate 10 million hectares of India's cropland, or nearly one tenth of the total. She sees a similar potential for China, which is now also expanding its drip irrigated area to save scarce water.[25]

In the Punjab, with its extensive double cropping of wheat and rice, fast-falling water tables led the state farmers' commission in 2007 to recommend a delay in transplanting rice from May to late June or early July. This would reduce irrigation water use by roughly one third since transplanting would coincide with the arrival of the monsoon. This reduction in groundwater use would help stabilize the water table, which has fallen from 5 meters below the surface to 30 meters in parts of the state.[26]

Institutional shifts—specifically, moving the responsibility for managing irrigation systems from government agencies to local water users associations—can facilitate the more efficient use of water. In many countries farmers are organizing locally so they can assume this responsibility, and since they have an economic stake in good water management, they tend to do a better job than a distant government agency.[27]

Mexico is a leader in developing water users associations. As of 2002, farmers associations managed more than 80 percent of Mexico's publicly irrigated land. One advantage of this shift for the government is that the cost of maintaining the irrigation system is assumed locally, reducing the drain on the treasury. This means that associations often need to charge more for irrigation water, but for farmers the production gains from managing their water supply themselves more than outweigh this additional outlay.[28]

In Tunisia, where water users associations manage both irrigation and residential water, the number of associations increased from 340 in 1987 to 2,575 in 1999, covering much of the country. Many other countries now have such bodies managing their water resources. Although the early groups were organized to deal with large publicly developed irrigation systems, some recent ones have been formed to manage local groundwater irrigation as well. Their goal is to stabilize the water table to avoid aquifer depletion and the economic disruption that it brings to the community.[29]

Low water productivity is often the result of low water prices. In many countries, subsidies lead to irrationally low water prices, creating the impression that water is abundant when in fact it is scarce. As water becomes scarce, it needs to be priced accordingly. Provincial governments in northern China are raising water prices in small increments to discourage waste. A higher water price affects all water users, encouraging investment in more water-efficient irrigation technologies, industrial processes, and household appliances.[30]

What is needed now is a new mindset, a new way of thinking about water use. For example, shifting to more water-efficient crops wherever possible boosts water productivity. Rice production is being phased out around Beijing because rice is such a thirsty crop. Similarly, Egypt restricts rice production in favor of wheat.[31]

Any measures that raise crop yields on irrigated land also raise the productivity of irrigation water. Similarly, any measures that convert grain into animal protein more efficiently in effect increase water productivity.

For people consuming unhealthy amounts of livestock products, moving down the food chain reduces water use. In the United States, where annual consumption of grain as food and feed averages some 800 kilograms (four fifths of a ton) per person, a modest reduction in the consumption of meat, milk, and eggs could easily cut grain use per person by 100 kilograms. For 300 million Americans, such a reduction would cut grain use by 30 million tons and irrigation water use by 30 billion tons.[32]

Reducing water use to the sustainable yield of aquifers and rivers worldwide involves a wide range of measures not only in agriculture but throughout the economy. The more obvious steps, in addition to more water-efficient irrigation practices and more water-efficient crops, include adopting more water-efficient industrial processes and using more water-efficient household appliances. Recycling urban water supplies is another obvious step to consider in countries facing acute water shortages.



### Producing Protein More Efficiently

Another way to raise both land and water productivity is to produce animal protein more efficiently. With some 37 percent (about 740 million tons) of the world grain harvest used to produce animal protein, even a modest gain in efficiency can save a large quantity of grain.[33]

World meat consumption increased from 44 million tons in 1950 to 240 million tons in 2005, more than doubling consumption per person from 17 kilograms to 39 kilograms (86 pounds). Consumption of milk and eggs has also risen. In every society where incomes have risen, meat consumption has too, perhaps reflecting a taste that evolved over 4 million years of hunting and gathering.[34]

As both the oceanic fish catch and the production of beef on rangelands have leveled off, the world has shifted to grain-based production of animal protein to expand output. And as the demand for meat climbs, consumers are shifting from beef and pork to poultry and fish, sources that convert grain into protein most efficiently. Health concerns among industrial-country consumers are reinforcing this shift.

The efficiency with which various animals convert grain into protein varies widely. With cattle in feedlots, it takes roughly 7 kilograms of grain to produce a 1-kilogram gain in live weight. For pork, the figure is over 3 kilograms of grain per kilogram of weight gain, for poultry it is just over 2, and for herbivorous species of farmed fish (such as carp, tilapia, and catfish), it is less than 2. As the market shifts production to the more grain-efficient products, it raises the productivity of both land and water.[35]

Global beef production, most of which comes from rangelands, grew less than 1 percent a year from 1990 to 2006. Growth in the number of cattle feedlots was minimal. Pork production grew by 2.6 percent annually, and poultry by nearly 5 percent. The rapid growth in poultry production, going from 41 million tons in 1990 to 83 million tons in 2006 enabled poultry to eclipse beef in 1996, moving it into second place behind pork. World pork production, half of it now in China, overtook beef production in 1979 and has continued to widen the lead since then.[36]

Fast-growing, highly grain-efficient fish farm output may also overtake beef production within the next decade or so. In fact, aquaculture has been the fastest-growing source of animal protein since 1990, largely because herbivorous fish convert feed into protein so efficiently. Aquacultural output expanded from 13 million tons in 1990 to 48 million tons in 2005, growing by more than 9 percent a year.[37]

Public attention has focused on aquacultural operations that are environmentally inefficient or disruptive, such as the farming of salmon, a carnivorous species, and shrimp. These operations account for 4.7 million tons of output, less than 10 percent of the global farmed fish total, but they are growing fast. Salmon are inefficient in that they are fed other fish, usually as fishmeal, which comes either from fish processing wastes or from low-value fish caught specifically for this purpose. Shrimp farming often involves the destruction of coastal mangrove forests to create areas for the shrimp.[38]

Worldwide, aquaculture is dominated by herbivorous species—mainly carp in China and India, but also catfish in the United States and tilapia in several countries—and shellfish. This is where the great growth potential for efficient animal protein production lies.

China, the world's leading producer, accounts for an astounding two thirds of global fish farm output. Aquacultural production in China is dominated by finfish (mostly carp), which are produced inland in freshwater ponds, lakes, reservoirs, and rice paddies, and by shellfish (mostly oysters, clams, and mussels), which are produced mostly in coastal regions.[39]

Over time, China has also developed a fish polyculture using four types of carp that feed at different levels of the food chain, in effect emulating natural aquatic ecosystems. Silver carp and bighead carp are filter feeders, eating phytoplankton and zooplankton respectively. The grass carp, as its name implies, feeds largely on vegetation, while the common carp is a bottom feeder, living on detritus. These four species thus form a small ecosystem, with each filling a particular niche. This multispecies system, which converts feed into high-quality protein with remarkable efficiency, allowed China to produce some 14 million tons of carp in 2005.[40]

While poultry production has grown rapidly in China, as in other developing countries, it has been dwarfed by the phenomenal growth of aquaculture. Today aquacultural output in China—at 30 million tons—is double that of poultry, making it the first major country where fish farming has eclipsed poultry farming.[41]



China's aquaculture is often integrated with agriculture, enabling farmers to use agricultural wastes, such as pig or duck manure, to fertilize ponds, thus stimulating the growth of plankton on which the fish feed. Fish polyculture, which commonly boosts pond productivity over that of monocultures by at least half, is widely practiced in both China and India.[42]

With incomes now rising in densely populated Asia, other countries are following China's aquacultural lead. Among them are Thailand and Viet Nam. Viet Nam, for example, devised a plan in 2001 of developing 700,000 hectares of land in the Mekong Delta for aquaculture, which now produces more than 1 million tons of fish and shrimp.[43]

In the United States, catfish, which require less than 2 kilograms of feed per kilogram of live weight, is the leading aquacultural product. U.S. annual catfish production of 600 million pounds (about two pounds per person) is concentrated in the South. Mississippi, with easily 60 percent of U.S. output, is the catfish capital of the world.[44]

When we think of soybeans in our daily diet, it is typically as tofu, veggie burgers, or other meat substitutes. But most of the world's fast-growing soybean harvest is consumed indirectly in the beef, pork, poultry, milk, eggs, and farmed fish that we eat. Although not a visible part of our diets, the incorporation of soybean meal into feed rations has revolutionized the world feed industry, greatly increasing the efficiency with which grain is converted into animal protein.[45]

In 2007, the world's farmers produced 222 million tons of soybeans—1 ton for every 9 tons of grain produced. Of this, some 20 million tons were consumed directly as tofu or meat substitutes. The bulk of the remaining 202 million tons, after some was saved for seed, was crushed in order to extract 37 million tons of soybean oil, separating it from the highly valued, high-protein meal.[46]

The 160 million or so tons of protein-rich soybean meal that remain after the oil is extracted is fed to cattle, pigs, chicken, and fish. Combining soybean meal with grain in roughly one part meal to four parts grain dramatically boosts the efficiency with which grain is converted into animal protein, sometimes nearly doubling it.[47]

The world's three largest meat producers—China, the United States, and Brazil—now all rely heavily on soybean meal as a protein supplement in feed rations.[48]

The use of soybean meal in livestock feed, poultry, and fish both replaces some grain in feed and increases the efficiency with which the remaining grain is converted into livestock products. This helps explain why the share of the world grain harvest used for feed has not increased over the last 20 years even though production of meat, milk, eggs, and farmed fish has climbed. It also explains why world soybean production has increased nearly 14-fold since 1950.[49]

Mounting pressures on land and water resources have led to the evolution of some promising new animal protein production systems that are based on roughage rather than grain, such as milk production in India. Since 1970, India's milk production has increased more than fourfold, jumping from 21 million to 96 million tons. In 1997 India overtook the United States to become the world's leading producer of milk and other dairy products.[50]

The spark for this explosive growth came in 1965 when an enterprising young Indian, Dr. Verghese Kurien, organized the National Dairy Development Board, an umbrella organization of dairy cooperatives. The dairy coop's principal purpose was to market the milk from tiny herds that typically averaged two to three cows each, providing the link between the growing market for dairy products and the millions of village families who had only a small marketable surplus.[51]

Creating the market for milk spurred the fourfold growth in output. In a country where protein shortages stunt the growth of so many children, expanding the milk supply from less than half a cup per person a day 30 years ago to one cup today represents a major advance.[52]

What is so remarkable is that India has built the world's largest dairy industry almost entirely on roughage—wheat straw, rice straw, corn stalks, and grass gathered from the roadside. Even so, the value of the milk produced each year now exceeds that of the rice harvest.[53]

A second new protein production model, one that also relies



on ruminants and roughage, has evolved in four provinces in eastern China—Hebei, Shangdong, Henan, and Anhui—where double cropping of winter wheat and corn is common. Although wheat straw and cornstalks are often used as fuel for cooking, villagers are shifting to other sources of energy for this, which lets them feed the straw and cornstalks to cattle. Supplementing this roughage with small amounts of nitrogen in the form of urea allows the microflora in the complex four-stomach digestive system of cattle to convert roughage into animal protein more efficiently.[54]

These four crop-producing provinces in China, dubbed the Beef Belt by officials, use crop residues to produce much more beef than the vast grazing provinces in the northwest do. The use of crop residues to produce milk in India and beef in China lets farmers reap a second harvest from the original grain crop, thus boosting both land and water productivity.[55]

Although these new protein models have evolved in India and China, both densely populated countries, similar systems can be adopted in other countries as population pressures intensify, as demand for meat and milk increases, and as farmers seek new ways to convert plant products into animal protein.

The world desperately needs more new protein production techniques such as these. Meat consumption is growing twice as fast as population, egg consumption is growing nearly three times as fast, and growth in the demand for fish—both from the oceans and from fish farms—is also outpacing that of population.[56]

While the world has had many years of experience in feeding an additional 70 million people each year, it has no experience with some 5 billion people striving to move up the food chain at the same time. For a sense of what this translates into, consider what has happened in China, where record economic growth has in effect telescoped history, showing how diets change when incomes rise rapidly. As recently as 1978, meat consumption in China consisted mostly of modest amounts of pork. Since then, consumption of meat—pork, beef, poultry, and mutton—has climbed severalfold, pushing China's total meat consumption far above that of the United States.[57]

While diversifying diets has dramatically improved nutrition in China, in most of the developing world nutritional disorders remain. For example, half the women in the developing world suffer from anemia, the world's most common nutritional deficiency. Diets high in starchy food and low in iron-rich foods, such as leafy green vegetables, shellfish, nuts, and red meat, lead to insufficient iron in the diet, which in turn leads to low birthweights and high infant and maternal mortality.[58]

Encouragingly, a decade of research by the Canadian-based Micronutrient Initiative has succeeded in fortifying salt with iodine and iron together. Just as iodine fortification of salt eliminated iodine deficiency diseases, so, too, can the addition of iron eliminate iron deficiency diseases. This double-fortified salt is being introduced initially in India, Kenya, and Nigeria. The prospect of eliminating iron deficiency disorders at an annual cost of 20¢ per person is one of the most exciting new options for improving the human condition in this new century.[59]

**Moving Down the Food Chain**

One of the questions I am most often asked is, "How many people can the earth support?" I answer with another question: "At what level of food consumption?" Using round numbers, at the U.S. level of 800 kilograms of grain per person annually for food and feed, the 2-billion-ton annual world harvest of grain would support 2.5 billion people. At the Italian level of consumption of close to 400 kilograms, the current harvest would support 5 billion people. At the 200 kilograms of grain consumed by the average Indian, it would support a population of 10 billion.[60]

In every society where incomes rise, people move up the food chain, eating more animal protein as beef, pork, poultry, milk, eggs, and seafood. The mix of animal products varies with geography and culture, but the shift to more livestock products as purchasing power increases appears to be universal.

As consumption of livestock products, poultry, and farmed fish rises, grain use per person also rises. Of the roughly 800 kilograms of grain consumed per person each year in the United States, about 100 kilograms is eaten directly as bread, pasta, and breakfast cereals, while the bulk of the grain is consumed indirectly in the form of livestock and poultry products. By contrast, in India, where people consume just under 200 kilograms of grain per year, or roughly a pound per day, nearly all grain is eaten directly to satisfy basic food energy needs. Little is available for conversion into livestock products.[61]



Of the three countries just cited, life expectancy is highest in Italy even though U.S. medical expenditures per person are much higher. People who live very low or very high on the food chain do not live as long as those in an intermediate position. Those consuming a Mediterranean type diet that includes meat, cheese, and seafood, but all in moderation, are healthier and live longer. People living high on the food chain, such as Americans or Canadians, can improve their health by moving down the food chain. For those who live in low-income countries like India, where a starchy staple such as rice can supply 60 percent or more of total caloric intake, eating more protein-rich foods can improve health and raise life expectancy.[62]

In agriculture we often look at how climate affects the food supply but not at how what we eat affects climate. While we understand rather well the link between climate change and the fuel efficiency of the cars we buy, we do not have a comparable understanding of the climate effect of various dietary options. Gidon Eshel and Pamela A. Martin of the University of Chicago have addressed this issue. They begin by noting that the energy used in the food economy to provide the typical American diet and that used for personal transportation are roughly the same. In fact, the range between the more and less carbon-intensive transportation options and dietary options is each about 4 to 1. With cars, the Toyota Prius, a gas-electric hybrid, uses scarcely one fourth as much fuel as a Chevrolet Suburban SUV. Similarly with diets, a plant-based diet requires roughly one fourth as much energy as a diet rich in red meat. Shifting from a diet rich in red meat to a plant-based diet cuts greenhouse gas emissions as much as shifting from a Suburban SUV to a Prius. [63]

The inclusion of soybean meal in feed rations to convert grain into animal protein more efficiently, the shift by consumers to more grain-efficient forms of animal protein, and the movement of consumers down the food chain all can help reduce the demand for land, water, and fertilizer. This reduces carbon emissions and thus helps to stabilize climate as well.

**Action on Many Fronts**

At this writing in early October 2007, the food prospect does not look particularly promising. Grain prices in recent days have reached historic highs. Wheat has gone over $9 a bushel for the first time in history—more than double the figure a year earlier. International food aid flows are being slashed as rising grain prices collide with fixed budgets.[64]

If we continue with business as usual, the number of hungry people will soar. More and more, those on the lower rungs of the global economic ladder are losing their tenuous grip and are beginning to fall off. Cheap food may now be history.

Historically, the responsibility for food security rested largely with the Ministry of Agriculture. During the last half of the last century, ensuring adequate supplies of grain in the world market at a time of surplus production capacity was a relatively simple matter. Whenever the world grain harvest fell short and prices started to rise, the U.S. Department of Agriculture would return to production the cropland that had been idled under commodity-supply management programs, thus boosting output and stabilizing prices. This era ended in 1996 when the United States discontinued its annual cropland set-aside program.[65]

Now in our overpopulated, climate-changing, water-scarce world, food security is a matter for the entire society and for all government ministries. Since hunger is almost always the result of poverty, eradicating hunger depends on eradicating poverty. And where populations are outrunning their land and water resources, eradicating hunger also depends on stabilizing population. Our Plan B goal is to stabilize world population by 2040 at the 8-billion level. This will not be easy, but the alternative may be a halt in population growth because of rising mortality.

The new reality is that the Ministry of Energy may have a greater influence on future food security than the Ministry of Agriculture. The principal threat to food security today is climate change from the burning of fossil fuels. It is the Ministry of Energy's responsibility to minimize crop-withering heat waves, to prevent the melting of the glaciers that feed Asia's major rivers during the dry season, and to prevent the ice sheet melting that would inundate the river deltas and floodplains that produce much of the Asian rice harvest.

And where water is often a more serious constraint on expanding food production than land, it will be up to the Ministry of Water Resources to do everything possible to raise the



efficiency of water use. With water, as with energy, the principal opportunities now are on the demand side in increasing water-use efficiency, not on expanding the supply.

In a world where cropland is scarce and becoming more so, decisions made in the Ministry of Transportation on whether to develop auto-centered systems or more-diversified transport systems that are less land-intensive, including light rail, buses, and bicycles, will directly affect world food security. Transportation policies that diversify transport systems and reduce fossil fuel use will also help stabilize climate.

Decisions made by governments on the production of crop-based automotive fuels are already affecting grain supplies and prices. Given the turmoil in world grain markets in late 2007, it is time for the U.S. government to place a moratorium on the licensing of any more grain-based ethanol distilleries.

And finally, we have a role to play as individuals. Whether we bike or drive to work will affect carbon emissions, climate change, and food security. The size of the car we drive to the supermarket may affect the size of the bill at the supermarket checkout counter. If we are living high on the food chain, we can move down, improving our health while helping to stabilize climate. Food security is something in which we all have a stake—and a responsibility.