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Pushing Beyond the Earth's Limits

When historians look back on our times, the last half of the twentieth century will undoubtedly be labeled "the era of growth." Take population. In 1950, there were 2.5 billion people in the world. By 2000, there were 6 billion. There has been more growth in world population since 1950 than during the preceding 4 million years.[1]

Recent growth in the world economy is even more remarkable. During the last half of the twentieth century, the world economy expanded sevenfold. Most striking of all, the growth in the world economy during the single year of 2000 exceeded that of the entire nineteenth century. Economic growth, now the goal of governments everywhere, has become the status quo. Stability is considered a departure from the norm.[2]

As the economy grows, its demands are outgrowing the earth, exceeding many of the planet's natural capacities. While the world economy multiplied sevenfold in just 50 years, the earth's natural life-support systems remained essentially the same. Water use tripled, but the capacity of the hydrological system to produce fresh water through evaporation changed little. The demand for seafood increased fivefold, but the sustainable yield of oceanic fisheries was unchanged. Fossil fuel burning

raised carbon dioxide (CO_2) emissions fourfold, but the capacity of nature to absorb CO_2 changed little, leading to a buildup of CO_2 in the atmosphere and a rise in the earth's temperature. As human demands surpass the earth's natural capacities, expanding food production becomes more difficult.[3]

Losing Agricultural Momentum

Environmentalists have been saying for years that if the environmental trends of recent decades continued the world would one day be in trouble. What was not clear was what form the trouble would take and when it would occur. It now seems likely to take the form of tightening food supplies, and within the next few years. Indeed, China's forays into the world market in early 2004 to buy 8 million tons of wheat could mark the beginning of the global shift from an era of grain surpluses to one of grain scarcity.[4]

World grain production is a basic indicator of dietary adequacy at the individual level and of overall food security at the global level. After nearly tripling from 1950 to 1996, the grain harvest stayed flat for seven years in a row, through 2003, showing no increase at all. And in each of the last four of those years, production fell short of consumption. The shortfalls of nearly 100 million tons in 2002 and again in 2003 were the largest on record.[5]

With consumption exceeding production for four years, world grain stocks dropped to the lowest level in 30 years. (See Figure 1–1.) The last time stocks were this low, in 1972–74, wheat and rice prices doubled. Importing countries competed vigorously for inadequate supplies. A politics of scarcity emerged—with some countries, such as the United States, restricting exports.[6]

In 2004 a combination of stronger grain prices at planting time and the best weather in a decade yielded a

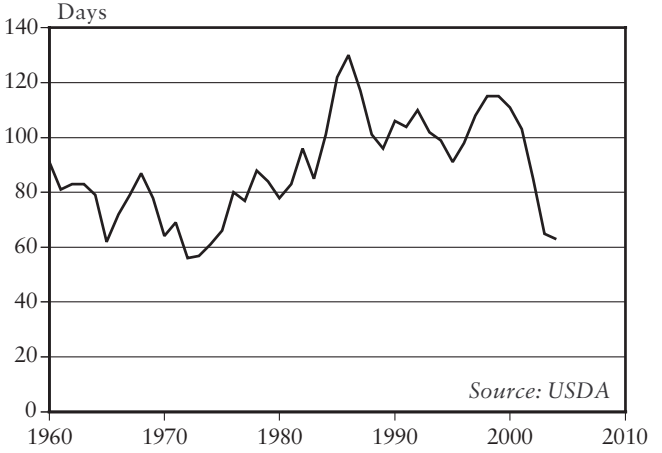

Figure 1–1. *World Grain Stocks as Days of Consumption, 1960–2004*

substantially larger harvest for the first time in eight years. Yet even with a harvest that was up 124 million tons from that in 2003, the world still consumed all the grain it produced, leaving none to rebuild stocks. If stocks cannot be rebuilt in a year of exceptional weather, when can they?[7]

From 1950 to 1984 world grain production expanded faster than population, raising the grain produced per person from 250 kilograms to the historical peak of 339 kilograms, an increase of 34 percent. This positive development initially reflected recovery from the disruption of World War II, and then later solid technological advances. The rising tide of food production lifted all ships, largely eradicating hunger in some countries and substantially reducing it in many others.[8]

Since 1984, however, grain harvest growth has fallen behind that of population, dropping the amount of grain produced per person to 308 kilograms in 2004,

down 9 percent from its historic high point. Fortunately, part of the global decline was offset by the increasing efficiency with which feedgrains are converted into animal protein, thanks to the growing use of soybean meal as a protein supplement. Accordingly, the deterioration in nutrition has not been as great as the bare numbers would suggest.[9]

The one region where the decline in grain produced per person is unusually steep and where it is taking a heavy human toll is Africa. In addition to the nutrient depletion of soils and the steady shrinkage in grainland per person from population growth in recent decades, Africa must now contend with the loss of adults to AIDS, which is depleting the rural work force and undermining agriculture. From 1960 through 1981, grain production per person in sub-Saharan Africa ranged between 140 and 160 kilograms per person. (See Figure 1–2.) Then from 1980 through 2001 it fluctuated largely between 120

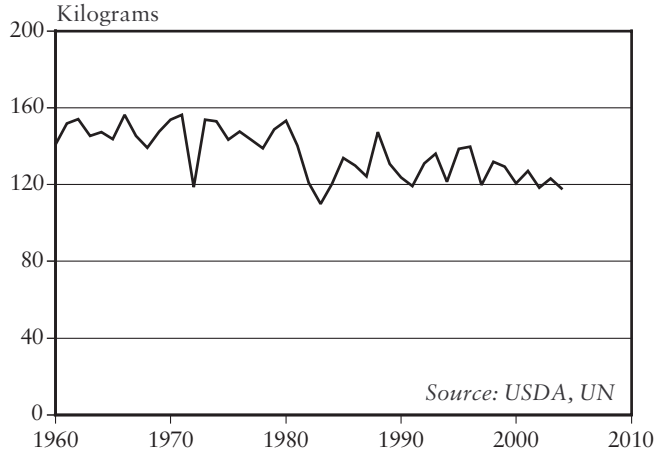

Figure 1–2. *Grain Production Per Person in Sub-Saharan Africa, 1960–2004*

and 140 kilograms. And in two of the last three years, it has been below 120 kilograms—dropping to a level that leaves millions of Africans on the edge of starvation.[10]

Several long-standing environmental trends are contributing to the global loss of agricultural momentum. Among these are the cumulative effects of soil erosion on land productivity, the loss of cropland to desertification, and the accelerating conversion of cropland to nonfarm uses. All are taking a toll, although their relative roles vary among countries.

Now two newer environmental trends—falling water tables and rising temperatures—are slowing the growth in world food production, as described later in this chapter. (See also Chapters 6 and 7.) In addition, farmers are faced with a shrinking backlog of unused technology. The high-yielding varieties of wheat, rice, and corn that were developed a generation or so ago are now widely used in industrial and developing countries alike. They doubled and tripled yields, but there have not been any dramatic advances in the genetic yield potential of grains since then.[11]

The use of fertilizer, which removed nutrient constraints and helped the new high-yielding varieties realize their full genetic potential during the last half-century, has now plateaued or even declined slightly in key food-producing countries. Among these are the United States, countries in Western Europe, Japan, and now possibly China as well. Meanwhile, the rapid growth in irrigation that characterized much of the last half-century has also slowed. Indeed, in some countries the irrigated area is shrinking.[12]

The bottom line is that it is now more difficult for farmers to keep up with the growing demand for grain. The rise in world grainland productivity, which averaged over 2 percent a year from 1950 to 1990, fell to scarcely 1

percent a year from 1990 to 2000. This will likely drop further in the years immediately ahead.[13]

If the rise in land productivity continues to slow and if population continues to grow by 70 million or more per year, governments may begin to define national security in terms of food shortages, rising food prices, and the emerging politics of scarcity. Food insecurity may soon eclipse terrorism as the overriding concern of national governments.[14]

Growth: The Environmental Fallout

The world economy, as now structured, is making excessive demands on the earth. Evidence of this can be seen in collapsing fisheries, shrinking forests, expanding deserts, rising CO_2 levels, eroding soils, rising temperatures, falling water tables, melting glaciers, deteriorating grasslands, rising seas, rivers that are running dry, and disappearing species.

Nearly all these environmentally destructive trends adversely affect the world food prospect. For example, even a modest rise of 1 degree Fahrenheit in temperature in mountainous regions can substantially increase rainfall and decrease snowfall. The result is more flooding during the rainy season and less snowmelt to feed rivers during the dry season, when farmers need irrigation water.[15]

Or consider the collapse of fisheries and the associated leveling off of the oceanic fish catch. During the last half-century the fivefold growth in the world fish catch that satisfied much of the growing demand for animal protein pushed oceanic fisheries to their limits and beyond. Now, in this new century, we cannot expect any growth at all in the catch. All future growth in animal protein supplies can only come from the land, putting even more pressure on the earth's land and water resources.[16]

Farmers have long had to cope with the cumulative effects of soil erosion on land productivity, the loss of cropland to nonfarm uses, and the encroachment of deserts on cropland. Now they are also being battered by higher temperatures and crop-scorching heat waves. Likewise, farmers who once had assured supplies of irrigation water are now forced to abandon irrigation as aquifers are depleted and wells go dry. Collectively this array of environmental trends is making it even more difficult for farmers to feed adequately the 70 million people added to our ranks each year.[17]

Until recently, the economic effects of environmental trends, such as overfishing, overpumping, and overplowing, were largely local. Among the many examples are the collapse of the cod fishery off Newfoundland from overfishing that cost Canada 40,000 jobs, the halving of Saudi Arabia's wheat harvest as a result of aquifer depletion, and the shrinking grain harvest of Kazakhstan as wind erosion claimed half of its cropland.[18]

Now, if world food supplies tighten, we may see the first global economic effect of environmentally destructive trends. Rising food prices could be the first economic indicator to signal serious trouble in the deteriorating relationship between the global economy and the earth's ecosystem. The short-lived 20-percent rise in world grain prices in early 2004 may turn out to be a warning tremor before the quake.[19]

Two New Challenges

As world demand for food has tripled, so too has the use of water for irrigation. As a result, the world is incurring a vast water deficit. But because this deficit takes the form of aquifer overpumping and falling water tables, it is nearly invisible. Falling water levels are often not discovered until wells go dry.[20]

The world water deficit is historically recent. Only within the last half-century, with the advent of powerful diesel and electrically driven pumps, has the world had the pumping capacity to deplete aquifers. The worldwide spread of these pumps since the late 1960s and the drilling of millions of wells, mostly for irrigation, have in many cases pushed water withdrawal beyond the aquifer's recharge from rainfall. As a result, water tables are now falling in countries that are home to more than half of the world's people, including China, India, and the United States—the three largest grain producers.[21]

Groundwater levels are falling throughout the northern half of China. Under the North China Plain, they are dropping one to three meters (3–10 feet) a year. In India, they are falling in most states, including the Punjab, the country's breadbasket. And in the United States, water levels are falling throughout the southern Great Plains and the Southwest. Overpumping creates a false sense of food security: it enables us to satisfy growing food needs today, but it almost guarantees a decline in food production tomorrow when the aquifer is depleted.[22]

With 1,000 tons of water required to produce 1 ton of grain, food security is closely tied to water security. Seventy percent of world water use is for irrigation, 20 percent is used by industry, and 10 percent is for residential purposes. As urban water use rises even as aquifers are being depleted, farmers are faced with a shrinking share of a shrinking water supply.[23]

At the same time that water tables are falling, temperatures are rising. As concern about climate change has intensified, scientists have begun to focus on the precise relationship between temperature and crop yields. Crop ecologists at the International Rice Research Institute in the Philippines and at the U.S. Department of Agriculture (USDA) have jointly concluded that with each 1-degree

Celsius rise in temperature during the growing season, the yields of wheat, rice, and corn drop by 10 percent.[24]

Over the last three decades, the earth's average temperature has climbed by nearly 0.7 degrees Celsius, with the four warmest years on record coming during the last six years. In 2002, record-high temperatures and drought shrank grain harvests in both India and the United States. In 2003, it was Europe that bore the brunt of the intense heat. The record-breaking August heat wave that claimed 35,000 lives in eight nations withered grain harvests in virtually every country from France in the west through the Ukraine in the east.[25]

The Intergovernmental Panel on Climate Change projects that during this century, with a business-as-usual scenario, the earth's average temperature will rise by 1.4–5.8 degrees Celsius (2–10 degrees Fahrenheit). These projections are for the earth's average temperature, but the rise is expected to be much greater over land than over the oceans, in the higher latitudes than in the equatorial regions, and in the interior of continents than in the coastal regions. This suggests that increases far in excess of the projected average are likely for regions such as the North American breadbasket—the region defined by the Great Plains of the United States and Canada and the U.S. Corn Belt. Today's farmers face the prospect of temperatures higher than any generation of farmers since agriculture began.[26]

The Japan Syndrome

When studying the USDA world grain database more than a decade ago, I noted that if countries are already densely populated when they begin to industrialize rapidly, three things happen in quick succession to make them heavily dependent on grain imports: grain consumption climbs as incomes rise, grainland area shrinks,

and grain production falls. The rapid industrialization that drives up demand simultaneously shrinks the cropland area. The inevitable result is that grain imports soar. Within a few decades, countries can go from being essentially self-sufficient to importing 70 percent or more of their grain. I call this the "Japan syndrome" because I first recognized this sequence of events in Japan, a country that today imports 70 percent of its grain.[27]

In a fast-industrializing country, grain consumption rises rapidly. Initially, rising incomes permit more direct consumption of grain, but before long the growth shifts to the greater indirect consumption of grain in the form of grain-intensive livestock products, such as pork, poultry, and eggs.

Once rapid industrialization is under way, it is usually only a matter of years before the grainland area begins to shrink. Among the trends leading to this are the abandonment of marginal cropland, the loss of rural labor needed for multiple cropping, and a shift of grainland to the production of fruits, vegetables, and other high-value crops.

First, as a country industrializes and modernizes, cropland is used for industrial and residential developments. As automobile ownership spreads, the construction of roads, highways, and parking lots also takes valuable land away from agriculture. In situations where farmers find themselves with fragments of land that are too small to be economically cultivated, they often simply abandon their plots, seeking employment elsewhere.

Second, as rapid industrialization pulls labor out of the countryside, it often leads to less double cropping, a practice that depends on quickly harvesting one grain crop once it is ripe and immediately preparing the seedbed for the next crop. With the loss of workers as young people migrate to cities, the capacity to do this diminishes.

Third, as incomes rise, diets diversify, generating

demand for more fruits and vegetables. This in turn leads farmers to shift land from grain to these more profitable, high-value crops.

Japan was essentially self-sufficient in grain when its grain harvested area peaked in 1955. Since then the grainland area has shrunk by more than half. The multiple-cropping index has dropped from nearly 1.4 crops per hectare per year in 1960 to scarcely 1 today. Some six years after Japan's grain area began to shrink, the shrinkage overrode the rise in land productivity and overall production began to decline. With grain consumption climbing and production falling, grain imports soared. (See Figure 1–3.) By 1983 imports accounted for 70 percent of Japan's grain consumption, a level they remain at today.[28]

A similar analysis for South Korea and Taiwan shows a pattern that is almost identical with that of Japan. In both cases, the decline in grain area was followed roughly a decade later by a decline in production. Perhaps this

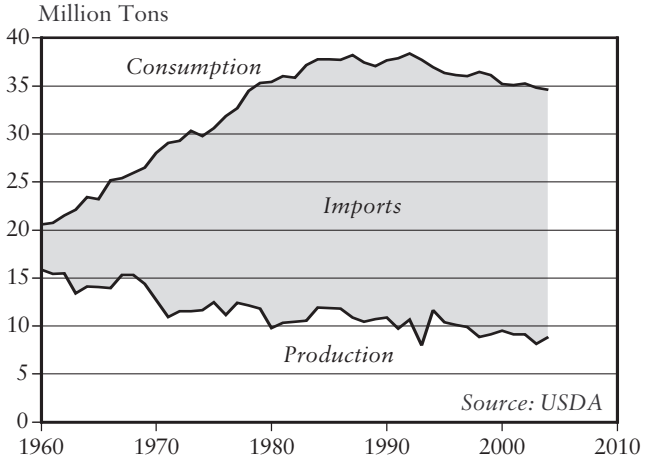

Figure 1–3. *Grain Production, Consumption, and Imports in Japan, 1960–2004*

should not be surprising, since the forces at work in the two countries are exactly the same as in Japan. And, like Japan, both South Korea and Taiwan now import some 70 percent of their total grain supply.[29]

Based on the sequence of events in these three countries that affected grain production, consumption, and imports—the Japan syndrome—it was easy to anticipate the precipitous decline in China's grain production that began in 1998 (as described in the next section). The obvious question now is which other countries will enter a period of declining grain production because of the same combination of forces? Among those that come to mind are India, Indonesia, Bangladesh, Pakistan, Egypt, and Mexico.[30]

Of particular concern is India, home to nearly 1.1 billion people. In recent years, its economic growth has accelerated, averaging 6–7 percent a year. This growth, only slightly slower than that of China, is also beginning to consume cropland. So, too, are the needs of the 18 million people added each year to India's population. In addition to the grainland shrinkage associated with the Japan syndrome, the extensive overpumping of aquifers in India—which will one day deprive farmers of irrigation water—will also reduce grain production.[31]

Exactly when rapid industrialization in a country that is densely populated will translate into a decline in grain production is difficult to anticipate. Once production turns downward, countries often try to reverse the trend. But the difficulty of achieving this can be seen in Japan, where a rice support price that is four times the world market price has failed to expand production.[32]

The China Factor

China—the largest country in the world—is now beginning to experience the Japan syndrome. Perhaps the most

alarming recent world agricultural event is the precipitous fall in China's grain production since 1998. After an impressive climb from 90 million tons in 1950 to a peak of 392 million tons in 1998, China's grain harvest fell in four of the next five years, dropping to 322 million tons in 2003. For perspective, this decline of 70 million tons exceeds the entire grain harvest of Canada.[33]

Behind this harvest shrinkage of 18 percent from 1998 to 2003 is a decline in grain harvested area of 16 percent. The conversion of cropland to nonfarm uses, the shift of grainland to higher-value fruits and vegetables, and, in some of the more prosperous regions, a loss of the rural labor needed for multiple cropping are all shrinking China's grainland—just as they did Japan's.[34]

In addition, China is also losing grainland to the expansion of deserts and the loss of irrigation water, due to both aquifer depletion and diversion of water to cities. (See Chapter 8 for further discussion of these pressures.) Unfortunately for China, none of the forces that are shrinking the grainland area are easily countered.

Between 1998 and 2003, five consecutive harvest shortfalls dropped China's once massive stocks of grain to their lowest level in 30 years. With stocks now largely depleted, China's leaders—all of them survivors of the great famine of 1959–61, when 30 million people starved to death—are worried. For them, food security is not a trivial issue.[35]

Not surprisingly, China desperately wants to reverse the recent fall in grain production. In March 2004, Beijing announced an emergency supplemental appropriation, expanding the 2004 agricultural budget by one fifth ($3.6 billion) in an effort to encourage farmers to grow more grain. The support price for the early rice crop in 2004 was raised by 21 percent. While these two emergency measures did reverse the grain harvest decline tem-

porarily, whether they can reverse the trend over the longer term is doubtful.[36]

When China turns to the outside world for commodities, it can overwhelm world markets. For example, 10 years ago China was self-sufficient in soybeans. In 2004, it imported 22 million tons—quickly eclipsing Japan, the previous leading importer with 5 million tons.[37]

When wheat prices within China started climbing in the fall of 2003, the government dispatched wheat-buying delegations to Australia, Canada, and the United States. They purchased 8 million tons, and overnight China became the world's largest wheat importer.[38]

China is a fascinating case study because of its sheer size and extraordinary pace of industrial development. It has been the world's fastest-growing economy since 1980. The economic effects of this massive expansion can be seen in the rest of the world, but China is also putting enormous pressure on its own natural resource base. In the deteriorating relationship between the global economy and the earth's ecosystem, China is unfortunately on the cutting edge.[39]

With water, the northern half of China is literally drying out. Water tables are falling, rivers are going dry, and lakes are disappearing. In a 748-page assessment of China's water situation, the World Bank sounds the alarm. It foresees "catastrophic consequences for future generations" if water use and supply cannot quickly be brought back into balance. More immediately, if China cannot quickly restore a balance between the consumption of water and the sustainable yield of its aquifers and rivers, its grain imports will likely soar in the years ahead.[40]

For people not living in China, it is difficult to visualize how fast deserts are expanding. It can be likened to a war, yet it is not invading armies that are claiming the territory, but expanding deserts. Old deserts are advancing and new ones are forming, like guerrilla forces striking unexpectedly, forcing Beijing to fight on several fronts. Throughout northern and western China, some 24,000 villages have either been abandoned or partly depopulated as drifting sand has made farming untenable.[41]

On the food front, the issue within China is not hunger and starvation, as the nation now has a substantial cushion between consumption levels and minimal nutrition needs. Rather, the concern is rising food prices and the effect that this could have on political stability. China's leaders are striving for a delicate balance between food prices that will encourage production in the countryside but maintain stability in the cities.[42]

As noted earlier, smaller countries like Japan, South Korea, and Taiwan can import 70 percent or more of their grain, but if China turns to the outside world to meet even 20 percent of its grain needs, which would be close to 80 million tons, it will provide a huge challenge for grain exporters. The resulting rise in world grain prices could destabilize governments in low-income, grain-importing countries. The entire world thus has a stake in China's efforts to stabilize its agricultural resource base.[43]

The Challenge Ahead

It is difficult to overestimate the challenges the world faces over the next half-century. Not only are there a projected 3 billion more people to feed, but there are also an estimated 5 billion people who want to diversify their diets by moving up the food chain, eating more grain-intensive livestock products. On the supply side, the world's farmers must contend with traditional challenges, such as soil erosion and the loss of cropland to nonfarm uses, but now also with newer trends such as

falling water tables, the diversion of irrigation water to cities, and rising temperatures.[44]

At the World Food Summit in 1996 in Rome, 185 governments plus the European Community agreed that the number of hungry people needed to be reduced by half by 2015. Between 1990–92 and 1995–97, the number did decline by some 37 million from 817 million to 780 million, or over 7 million a year—but this was much less than the 20 million per year needed to reach the 2015 target. And then things got even worse. From 1995–97 to 1999–2001, the number of hungry people in the world began to increase, rising by 18 million to 798 million. This increase in hunger is not too surprising, given the lack of growth in the world grain harvest from 1996 to 2003.[45]

Against this backdrop of a slowly deteriorating food situation, there is the prospect that the Japan syndrome will soon take effect in other countries, shrinking their grain harvests. Is India's grain production likely to peak and start declining in the next few years, much as China's did after 1998? Or will India be able to hold off the loss of cropland to nonfarm uses and the depletion of aquifers long enough to eradicate most of its hunger? There are signs that the shrinkage in its grain area, which is a precursor to the shrinkage of overall production, may have begun.

Because aquifer depletion is recent, it is taking agricultural analysts into uncharted territory. It is clear, for example, that water tables are falling simultaneously in many countries and at an accelerating rate. Less clear is exactly when aquifers will be depleted and precisely how much this will reduce food production.

If the climate models projecting the effect of rising atmospheric CO_2 levels on the earth's temperature are anywhere near the mark, we are facing a future of higher temperatures. We do not know exactly how fast temperatures will rise, but in a world of rising temperatures, there is added reason to be concerned about world food security.[46]

On another front, in Africa the spread of HIV/AIDS is threatening the food security of the entire continent as the loss of able-bodied field workers shrinks harvests. In sub-Saharan Africa, disease begets hunger and hunger begets disease. In some villages, high HIV infection rates have claimed an entire generation of young adults, leaving only the elderly and children. Without a major intervention from the outside world, the continuing spread of the virus and hunger that is cutting life expectancy in half in some countries could take Africa back to the Dark Ages.[47]

In a world where the food economy has been shaped by an abundance of cheap oil, tightening world oil supplies will further complicate efforts to eradicate hunger. Modern mechanized agriculture requires large amounts of fuel for tractors, irrigation pumps, and grain drying. Rising oil prices may soon translate into rising food prices.

As we look at the prospect of swelling grain imports for Asia, where half the world's people live, and for Africa, the second most populous continent, we have to ask where the grain will come from. The countries that dominated world grain exports for the last half-century—the United States, Canada, Australia, and Argentina—may not be able to export much beyond current levels.[48]

U.S. grain production, though it has reached 350 million tons several times over the last two decades, has never risen much beyond this. U.S. grain exports, which two decades ago were running around 100 million tons a year, have averaged only 80 million tons in recent years as rising domestic grain use has more than absorbed any production gains. The potential for expansion in both

Canada and Australia is constrained by relatively low rainfall in their grain-growing regions. Argentina's grain production has actually declined over the last several years as land has shifted to soybeans.[49]

By contrast, countries such as Russia and the Ukraine—where population has stabilized or is declining and where there is some unrealized agricultural production potential—should be able to expand their grain exports at least modestly. However, the low yields that are characteristic of northerly countries that depend heavily on spring wheat, as Russia does, will likely prevent Russia from becoming a major grain exporter. The Ukraine has a somewhat more promising potential if it can provide farmers with the economic incentives they need to expand production. So, too, do Poland and Romania.[50]

Yet the likely increases in exports from these countries are small compared with the prospective import needs of China and, potentially, India. It is worth noting that the drop in China's grain harvest of 70 million tons over five years is equal to the grain exports of Canada, Australia, and Argentina combined.[51]

Argentina can expand its already large volume of soybean exports, but its growth potential for grain exports is limited by the availability of arable land. The only country that has the potential to substantially expand the world grainland area is Brazil with its vast *cerrado*, a savannah-like region that lies on the southern edge of the Amazon Basin. (See Chapter 9.) Because its soils require the heavy use of fertilizer and because transporting grain from Brazil's remote interior to distant world markets is costly, it would likely take substantially higher world grain prices for Brazil to emerge as a major exporter. Beyond this, would a vast expansion of cropland in Brazil's interior be sustainable? Or is its vulnerability to soil erosion likely to prevent it from making a long-term

contribution? And what will be the price paid in the irretrievable loss of ecosystems and plant and animal species?[52]

Ensuring future food security is a formidable challenge. Can we check the HIV epidemic before it so depletes Africa's adult population that starvation stalks the land? Can we arrest the steady shrinkage in grainland area per person, eliminate the overgrazing that is converting grasslands to desert, and reduce soil erosion losses below the natural rate of new soil formation? Can we simultaneously halt the advancing deserts that are engulfing cropland, check the rising temperature that threatens to shrink harvests, arrest the fall in water tables, and protect cropland from careless conversion to nonfarm uses?

Data for figures and additional information can be found at www.earth-policy.org/Books/Out/index.htm.