China's Water Shortage Could Shake World Food Security

An abrupt decline in the supply of irrigation water to China's farmers has aroused growing concern in the world's capitals.

by Lester R. Brown and Brian Halweil

An unexpectedly abrupt decline in the supply of water for China's farmers poses a rising threat to world food security. China depends on irrigated land to produce 70 percent of the grain for its huge population of 1.2 billion people, but it is drawing more and more of that water to supply the needs of its fast-growing cities and industries. As rivers run dry and aquifers are depleted, the emerging water shortages could sharply raise the country's demand for grain imports, pushing the world's total import needs beyond exportable supplies.

Any major threat to China's food self-sufficiency, if not addressed by strong new measures, would likely push up world grain prices, creating social and political instabilities in Third World cities—as previous WORLD WATCH articles have pointed out (see box, page 12). New information on the deteriorating water situation has confirmed the imminence of this possibility. The challenge now facing the Chinese government is how to meet the soaring water needs of its swelling urban and industrial sectors without undermining both its own agriculture and the world's food security.

The decline in China's capacity to irrigate its crops is coming at a time when depleted world grain stocks are near an all-time low. With its booming economy and huge trade surpluses, China can survive its water shortages by simply importing more of its food, because it can afford to pay more for grain. But low-income countries with growing grain deficits may not be able to pay these higher prices. For the 1.3 billion of the world's people who live on $1 a day or less, higher grain prices could quickly become life-threatening. The problem is now so clearly linked to global security that the U.S. National Intelligence Council (NIC), the umbrella over all U.S. intelligence agencies, has begun to monitor the situation with the kind of attention it once focused on Soviet military maneuvers.

This deepening concern led the NIC to sponsor a major interdisciplinary assessment of China's food prospect. Headed by Michael McElroy, chairman of Harvard University's Department of Earth and Planetary Sciences, the study used information from intelligence satellites to refine cropland area estimates, and commissioned computer modeling by the Sandia National Laboratory to assess the extent of future water shortages in each of China's river basins. The recently released study concluded that China will need massive grain imports in the decades ahead—a conclusion that meshes with earlier projections published by WORLD WATCH.

Signs of Stress

SINCE MID-CENTURY, the population of China has grown by nearly 700 million—an increase almost equivalent to adding the whole population of the world at the beginning of the Industrial Revolution. Most of that population has concentrated in the region through which several great rivers, including the Yellow and the Yangtze, flow. Those rivers provide the irrigation water needed to grow much of the food for China, as well as the water for its burgeoning cities and industries.

This dependence has placed a growing burden on the region's land and water resources, because the Chinese population has not been able to expand into new land the way the Americans once did with their westward expansion into the Great Plains and California. In China, the western half of the country is mostly desert or mountains. The resulting concentration of Chinese population, industry, and agriculture has been roughly equivalent to squeezing the entire U.S. population into the region east of the Mississippi, then multiplying it by five.

A quarter-century ago, with more and more of its water being pumped out for the country's multiplying needs, the Yellow River began to falter. In 1972, the water level fell so low that for the first time in China's long history it dried up before reaching the sea. It failed on 15 days that year, and intermittently over the next decade or so. Since 1985, it has run dry each year, with the dry period becoming progressively longer. In 1996, it was dry for 133 days. In 1997, a year exacerbated by drought, it failed to reach the sea for 226 days. For long stretches, it did not even reach Shandong Province, the last province it flows through en route to the sea. Shandong, the source of one-fifth of China's corn and one-seventh of its wheat, depends on the Yellow River for half of its irrigation water.

Although it is perhaps the most visible manifestation of water scarcity in China, the drying-up of the Yellow River is only one of many such signs. The Huai, a smaller river situated between the Yellow and Yangtze, was also drained dry in 1997, and failed to reach the sea for 90 days. Satellite photographs show hundreds of lakes disappearing and local streams going dry in recent years, as water tables fall and springs cease to flow.

The Fen river that runs through Taiyuan, the capital city of Shanxi province, no longer exists. The major river in the province, and the lifeline of Taiyuan, was emptied to fuel the city's coal industry. Big industrial wells driven more than 300 feet, and sometimes as much as 2,500 feet into the ground, tap Taiyuan's last remaining groundwater resources. Dan Goonaratnum, a water resources expert with the World Bank, notes that this city of 2 million "has come to the stage in which they either shift the population or divert water from the Yellow River," more than 200 miles away. Meanwhile, as water tables have fallen, millions of Chinese farmers are finding their wells pumped dry.

In the geography of water, there are two Chinas. The humid South includes the vast Yangtze River and a population of 700 million. The arid North includes the Yellow, Liao, Hai, and Huai Rivers, and has 550 million. While four-fifths of the water is in the South, two-thirds of the cropland is in the North. As a result, the water per hectare of cropland in the North is only one-eighth that in the South.

Although comprehensive hydrological data are not always available, key pieces of the water puzzle are beginning to emerge from various sources. A recent Chinese survey reported by Professor Liu Yonggong of China Agricultural University in Beijing indicated that the water table beneath much of the North China Plain, a region that produces some 40 percent of China's grain, has fallen an average of 1.5 meters (roughly 5 feet) per year over the last five years. A joint Sino-Japanese analysis of China's agricultural prospect reports that water tables are falling almost everywhere in China that the land is flat.

In the late summer of 1997, many of the irrigation wells in Shandong Province, which was experiencing its worst drought in 25 years, were not pumping. Chinese water analysts report frenzied well-drilling in some provinces as farmers chased the falling water table downward.

Of course, those farmers' ability to provide food enough for their nation is constrained by a range of factors in addition to water—by the construction of roads over once-productive farmland, by erosion of soil, by the diminishing benefits of fertilizer, and by a shrinking backlog of the technology used to raise land productivity. But it is the swelling diversion of irrigation water, combined with heavy losses to aquifer depletion, that has emerged as the most imminent threat to China's food security.

Projected Demand for Water

Even as the Yellow River, aquifers, and wells get drier, the need for water continues to swell. Between now and 2030, UN demographers project that China's population will increase from 1.2 billion to 1.5 billion, an increase that exceeds the entire population of the United States. Even if there were no changes in water consumption per person, this would boost the demand for water by one-fourth above current levels—but per-person consumption, too, is growing. It is expected to grow in all three of the end use sectors—agricultural, residential, and industrial.

In the agricultural sector, demand for irrigation water, now roughly 400 billion cubic meters or tons per year, is expected to reach 665 billion tons in 2030. As incomes rise, people are consuming more pork, poultry, beef, and eggs, and feedgrain use is growing. For example, to produce one kilogram of pork it takes four kilograms of grain, and one kilogram of chicken takes two kilograms of grain. More grain means more water (see Figure 1). According to the U.S. Department of Agriculture (USDA), between 1990 and 1997, consumption of pork climbed by a phenomenal 9 percent per year. Consumption of both beef and poultry, starting from a much smaller base, has climbed at over 20 percent per year. The brewing of beer, which is also made from grain, is growing at 7 percent annually.

In the residential sector, a similar compounding is occurring. At present, some 85 percent of all water withdrawals are for irrigation, but the residential share is increasing as China's population urbanizes and hundreds of millions turn from the village well to indoor plumbing with showers and flush toilets. Combined with projected increases in population, rising individual water use will boost residential water use from 31 billion tons in 1995 to 134 billion tons in 2030, a gain of more than four-fold.

The demand for water by industry is growing even faster. Assuming an economic growth of 5 percent a year from 1995 until 2030 (actual growth in the past decade has been more than twice that rate), industrial water use would increase from 52 billion tons to 269 billion tons (see table, page 14). The increase in residential and industrial water use together would total 320 billion tons of water during this 35-year span. If this water were used for irrigation, at 1,000 tons of water required per ton of grain produced, it would yield 320 million tons of grain, an amount approaching China's 1997 grain harvest of 380 million tons.

In other words, non-agricultural uses that are now straining the system by drawing only 15 percent of the supply would multiply nearly five times, while the agricultural needs now taking 85 percent would have increased as well. Obviously, that can't happen. Because consumption can't exceed the sustainable supply for long, China is facing fundamental changes in the way it distributes and uses its water.

Diversion, Depletion, and Pollution

Although 70 percent of the grain produced in China comes from irrigated land, the country is seeing its irrigation supply depleted on three fronts: the diversion of water from rivers and reservoirs to cities; the depletion of underground supplies in aquifers; and the increasing pollution caused by rapid industrialization. Politically, it is difficult for any government to deny people water for their showers and toilets, if they can afford to buy it—and China's urbanizing population increasingly can. And economically, farms can't compete with factories for water. As competition among farms, homes, and industries intensifies, farms inevitably lose out.

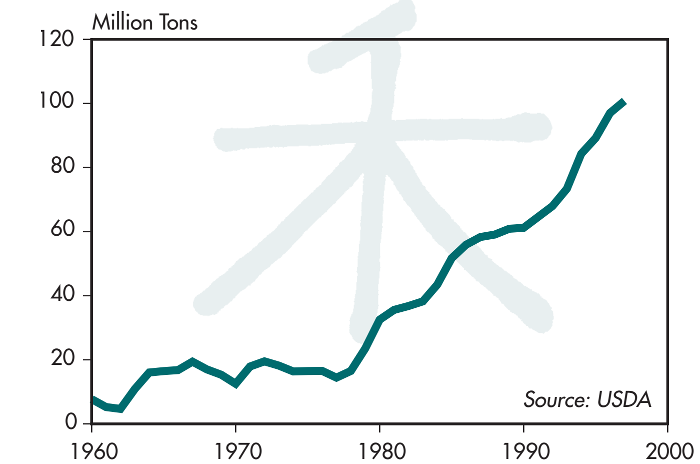


Figure 1: China: Grain Used for Feed, 1960–97

Of China's 617 largest cities, 300 are already facing water shortages. In those areas of North China where all available water is being used, these shortfalls can be filled only by diverting water from agriculture. In the spring of 1994, farmers in the region surrounding Beijing were denied access to reservoirs, their traditional source of irrigation water, because all the water was needed to satisfy the city's burgeoning demand. That established a pattern for water-stressed cities all over the North China Plain.

As for the demand from industry, agriculture simply cannot compete in China or anywhere else. A thousand tons of water produces one ton of wheat, which has a market value of $200, whereas the same amount of water used in industry yields an estimated $14,000 of output—70 times as much. Moreover, that economic advantage is reinforced by a political one: the need to provide jobs for some 14 million new entrants into the labor force each year. And, as China's old state-run corporations are cut back, massive layoffs are leaving millions of people unemployed. As it happens, water used in industry can also create a disproportionately large number of jobs. Since incomes are much higher in industry than in agriculture, the number of jobs a given amount of water can bring to industry versus agriculture is somewhat less than the 70 to 1 just mentioned, but the bottom line still is that shifting irrigation water to

The New Security Issue

World Watch has played a role not only in chronicling the emerging issue of global food security, but in shaping responses to it. In 1994, the magazine published Lester R. Brown's wake-up article, "Who Will Feed China?" At the time, the conventional wisdom held that China had always fed itself and would continue to do so, thus avoiding the prospect of seeing the world's total needs for imported grain far exceeding the total exportable supply and thereby causing world grain prices to soar dangerously. China's leaders resisted the prospect of importing grain on a scale that could let that happen; one high-ranking Chinese agricultural official even claimed that China would have a huge *surplus* of grain by 2025.

Brown's analysis showed a starkly different prospect. By taking into account such trends as China's rapid paving-over of cropland for new factories, roads, and housing, its diminishing returns on applications of fertilizer, and growing shortages of irrigation water, his calculations indicated that China was headed not toward a surplus but toward a large grain deficit—a situation that would severely jeopardize world food security by driving grain prices to levels the world's rising numbers of poor could never afford.

The World Watch piece was received with sharp skepticism at first, and the Chinese government called a press conference in Beijing to denounce it. But Brown's thesis soon began to be echoed in mainstream media. Three weeks after his article was published, an article appeared in the *New York Times* under a nearly identical title: "Who'll Feed China?" In the ensuing months, the article spawned conferences, seminars, and reassessments throughout the world. Still later, *Scientific American* published an article titled "Can China Feed Itself?"

While a sporadic debate continued in the media, a quiet concern was rising among government officials worldwide, some of whom were coming to recognize that water and food shortages could pose even greater threats to human security in the next century than the ideological threats that had preoccupied them during the Cold War. In Washington, the National Intelligence Council, concerned about the potential effects of rising grain prices on political stability, launched a major investigation—called the MEDEA Study on the Future of Chinese Agriculture. The study's initial findings, jointly issued by the NIC and CIA in January 1998, projected that China would need to import 175 million tons of grain by 2025—a figure that closely corroborated Brown's findings.

Projected Water Demand in China, 1995–2030
(billion tons)

	1995	2030
Residential	31	134
Industrial	52	269
Agricultural	400	665
Total	483	1,068

Source: Worldwatch Institute

industry creates many more jobs.

While farmers are losing out to cities and industries politically, they are also losing ground hydrologically. As the demand for underground water increases over time, the pumping eventually surpasses the natural recharge of the aquifer, which comes from precipitation in the upstream portion of the watershed. After this "sustainable yield threshold" is passed, the water table starts to fall. If demand continues to climb, the excess of pumping over the sustainable yield of the aquifer widens each year. As a result, the distance the water table falls increases each year.

Once the aquifer is depleted, the amount of water pumped is limited to the rate of recharge. It cannot be otherwise. If the pumping has been taking place at double the recharge when depletion occurs, then the pumping will be cut by half. If pumping has been five times the recharge, it will be cut by four fifths. Under the North China Plain, if the water table is falling 1.5 meters per year, then the pumping could easily be occurring at double the recharge rate. And if it is, the time will come when the amount of water pumped in this wheat and corn belt will be necessarily cut by half.

When farmers lose irrigation water, they either revert to dryland (rain-fed) farming if rainfall is sufficient or they abandon the land if it is not. For China, most of the land will simply revert to dryland agriculture. The yield will then decline by about one-half to two-thirds.

Unfortunately, even this stark arithmetic fails to fully convey the extent to which China's grainland irrigation water is being lost, because it doesn't account for losses to pollution. There are 50,000 kilometers of major rivers in China, and, according to the UN Food and Agriculture Organization, 80 percent of them are so degraded they no longer support fish. As a result of toxic discharge from cities and upstream enterprises, which include such highly polluting industries as paper mills, tanneries, oil-refineries and chemical plants, the Yellow River water is now loaded with heavy metals and other toxins that make it unfit even for irrigation, much less for human consumption, along much of its route.

Water pollution horror stories abound throughout China as farmers—for want of a cleaner source—irrigate with heavily polluted water. In Shanxi province, in the Yellow River watershed, rice has been found to contain excessive levels of chromium and lead, and cabbage is laced with cadmium. Along the length of the Yellow River, abnormally high rates of mental retardation, stunting, and developmental diseases are linked to elevated concentrations of arsenic and lead in the water and food.

As industrialization outpaces pollution control, more and more river water is rendered unsuitable for irrigation. In the heavily industrialized, heavily populated Yangtze valley, it may not be the diversion of water to industry that most threatens agriculture, but the pollution of water by industry, which renders it unsuitable for irrigation to begin with.

Basin-by-Basin Review

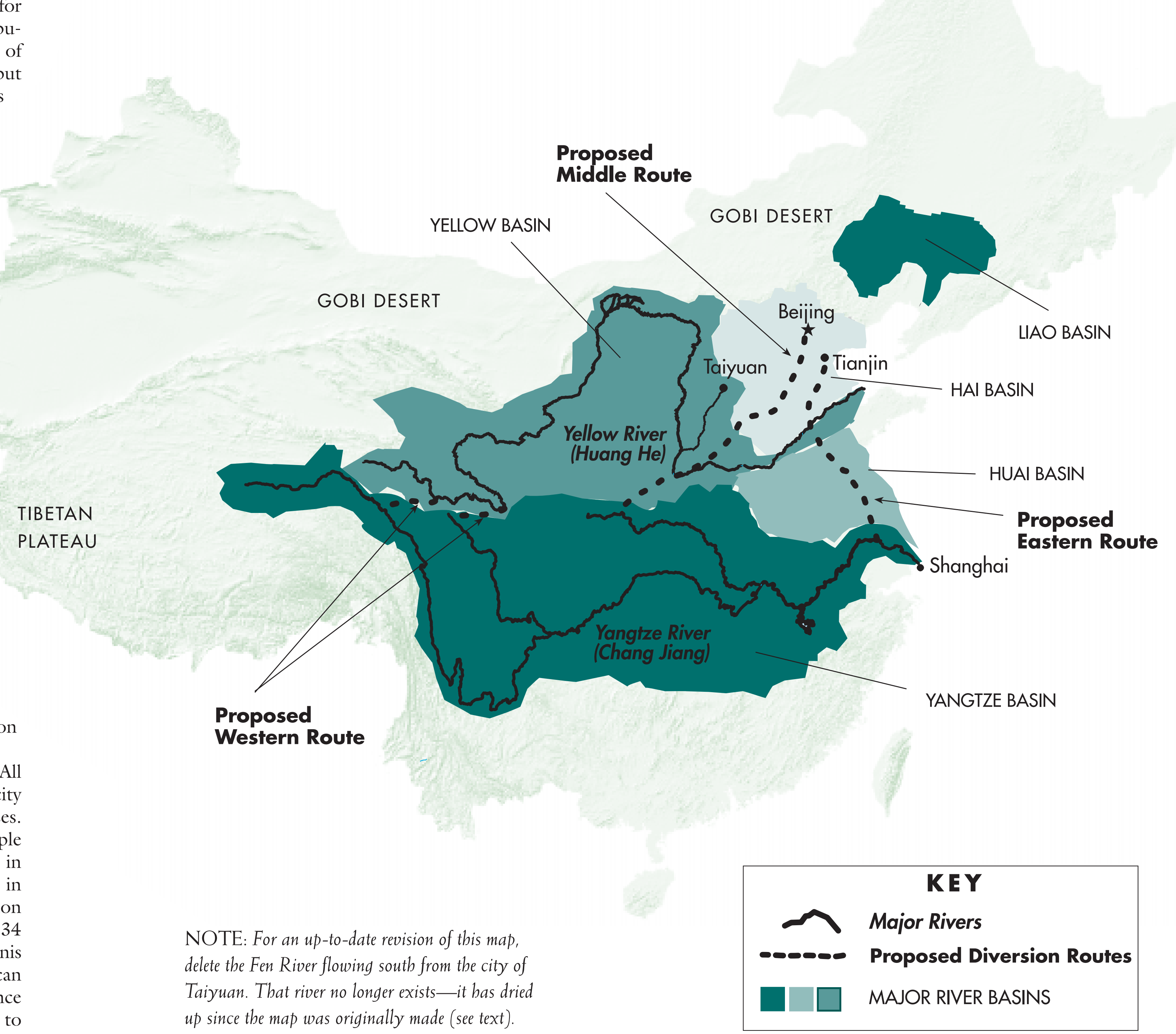
THE MOST MEANINGFUL WAY to assess the effect of excessive withdrawals, either from rivers or aquifers, is to analyze the situation in each river basin individually—as was done in the Sandia Laboratory modeling study. Sandia studied five basins—the Yangtze, Yellow, Hai, Huai, and Liao—in which some 900 million of China's 1.2 billion live and which produce a comparable share of its food (see map).

The Yangtze River, which dominates southern China, never runs dry. In this basin, water supplies appear to be sufficient to satisfy needs through 2030. That doesn't rule out sporadic local shortages as demand soars in the decades ahead, but at least the basin does not appear to face any severe constraints based on quantity.

To the north, the situation is more precarious. All four of the northern basins face acute water scarcity and a swelling diversion of water to nonfarm uses. The Hai basin, which is home to 92 million people and includes both Beijing and Tianjin, is now in chronic deficit. The projected water withdrawals in the basin in the year 2000, estimated at 55 billion cubic meters, far exceed the sustainable supply of 34 billion cubic meters, according to Sandia's Dennis Engi. This water deficit of 21 billion cubic meters can be satisfied only by groundwater mining. But once the aquifer is depleted, water pumping will drop to

Where Will the Water Come From?

China's geography confronts its planners with a colossal problem: whereas two-thirds of its agriculture is in the North, four-fifths of its water is in the South. Of the five watersheds where most of the country's people and farms are concentrated, four—containing 550 million people—are in the arid North. Engineers have proposed transporting water from the South, but the WORLD WATCH analysis suggests that a different strategy will be needed.



NOTE: *For an up-to-date revision of this map, delete the Fen River flowing south from the city of Taiyuan. That river no longer exists—it has dried up since the map was originally made (see text).*

the sustainable yield of the aquifer, cutting the water supply by nearly 40 percent. At a minimum, this indicates that the reallocation of irrigation water to cities, already underway in the region surrounding Beijing, will become basin-wide in the years ahead.

To the south lies the Yellow River basin, which is already suffering severe bouts of annual desiccation, but where conditions seem destined to worsen. Claims on the river itself, which originates in the Quighai-Tibet plateau and flows through eight provinces en route to the sea, are expected to soar in the years ahead, since this basin, which contains 105 million people, is designated for rapid industrialization. Each of the upstream provinces plans to increase its withdrawals from the river for residential and industrial uses.

Among the hundreds of projects that will be diverting water from the Yellow River's upper reaches in the years ahead is a plan to build a canal that will move 146 million cubic meters per year—equal to the annual water consumption of Newark, New Jersey—into Hohhot, the capital of Inner Mongolia. When this project is completed in 2003, this additional water will help to satisfy the swelling residential needs of 1.2 million people as well as the needs of expanding industries, including the all-important wool textile industry, which is supplied by the region's vast flocks of sheep.

Where Will the Grain Come From?

Demand and Supply Today

Grain is the world's basic food. Only a handful of countries can produce enough of it to feed their own people and still have enough to export. Most countries, because of environmental limits (arid land, mountains, etc.) in their territory, have to import at least some grain. **The total amount of grain available for export is about equal to the total import demand.**

Over the next quarter-century, however, demands for imports are expected to grow hugely, as populations rise in such grain-poor areas as North Africa and the Middle East.

. . . and in 2030

Global supply is unlikely to increase much. But as domestic demands increase, they will almost certainly eat up any increase in production. The world is unlikely to have any more grain available for export—if even as much—as it has now.

Meanwhile, China's production is expected to shrink as a result of its pervasive water scarcity, while its consumption will grow to the point where **China's import demand equals the whole world's export supply**—and China has the money to buy it. At the same time, **the rest of the world's import needs will have also grown,** in some areas immensely. But if China corners the market, there could be no grain available for the rest of the world to buy.

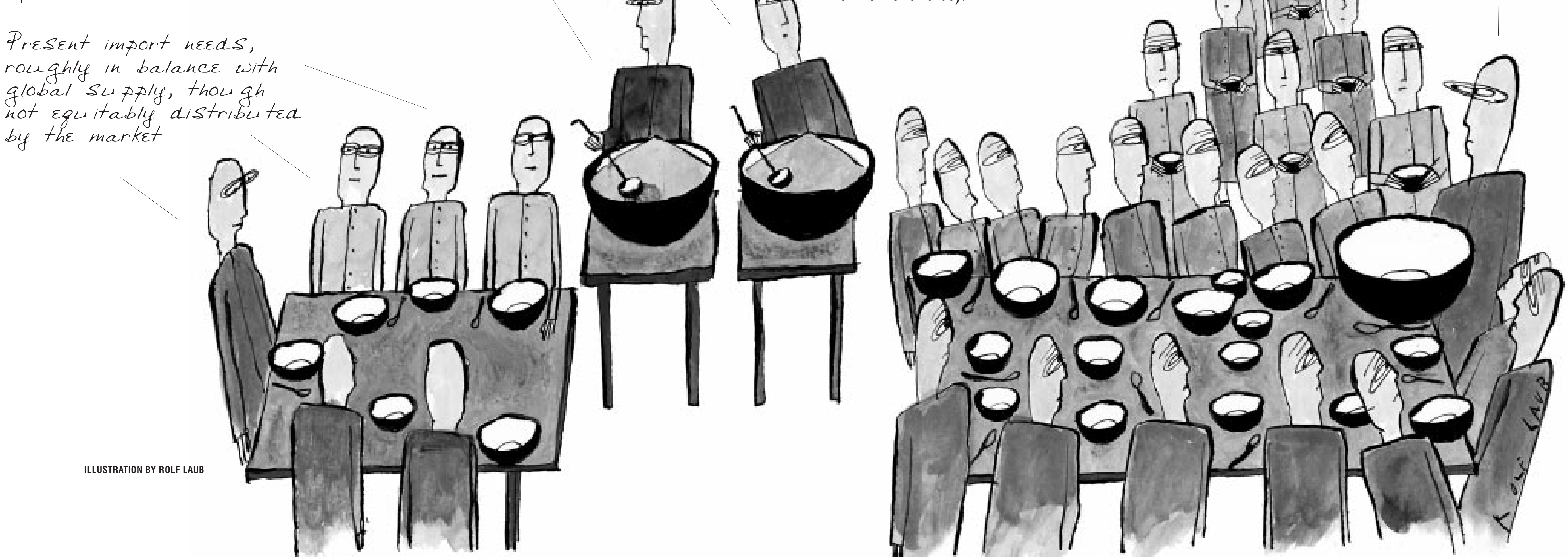


ILLUSTRATION BY ROLF LAUB

Another project, the Lijiaxia Hydropower Station, one of the largest in China, began operating its five 400,000-kilowatt turbines in 1997. It is only the third of many large power stations scheduled for construction on the upper reaches of the Yellow River. Hydroelectric engineers like to argue that such plants merely take the energy out of the river, not water. But hydroelectric reservoirs, which greatly expand the river's surface area, can increase annual water loss through evaporation by easily 10 percent of the reservoir's volume.

With the proliferating of new upstream projects, ever less water will flow to the already-depleted lower reaches of the basin. One result is that some companies are moving their factories upstream, both to assure an uninterrupted supply of water and to take advantage of the cheaper labor they can find there. If this trend continues, the Yellow River could become an inland river, one that never reaches the sea. This prospect leads to sleepless nights for agricultural officials in Beijing, because if the Yellow River fails to reach Shandong altogether, it would deprive the province of roughly half of its irrigation water. It would be a staggering setback, since Shandong has a larger share of China's grain harvest than Iowa and Kansas together have of the U.S. grain harvest.

Yet, the pressure to create jobs in upstream provinces is overwhelming. At the national level, the redistribution of income to the economically lagging interior may be essential to maintaining political stability and preventing a massive exodus to cities in the coastal provinces. The dilemma leaves the Beijing government walking a political tightrope, as it attempts to balance politically compelling upstream needs for indoor plumbing and jobs against increasingly urgent downstream needs for irrigation water.

Water Losses Reducing Harvest

It is a matter of mounting concern, not just to agricultural officials but increasingly to national leaders and security advisers, to know more precisely what happens to land productivity as the supply of irrigation water plummets. So far, little hard data has been compiled. The *China Daily* reported that in 1995, the failure of the Yellow River to reach Shandong Province lowered the grain harvest by 2.7 million tons, enough to feed 9 million people. If so, the effect of the river's running dry for twice as long in 1997 was likely far greater.

While much attention has focused on water shortages in cities, the villages are also experiencing acute deprivation—often with less recourse. At China's National People's Congress, convened in early March of 1998, delegate Wang Wenyuan pointed out that "Rural villages nationwide are facing annual shortages amounting to 30 billion cubic meters of water, which has cut grain production by 20 million tons…."

In assessing the effect of future water losses on food production in China, it would be helpful to know how much of existing irrigated grain production is based on the unsustainable use of water—or groundwater mining. In the United States, where only one-tenth of the grain harvest comes from irrigated land, irrigation water losses will not substantially alter the world grain supply. But in a country where 70 percent of an even larger grain harvest comes from irrigated land, and where groundwater mining is widespread, the impending consequences of aquifer depletion are far greater.

A second key question is how much irrigation water will be lost to nonfarm uses. We don't know how much of the country's projected growth of 103 billion tons in residential water use and 217 billion tons in industrial water use will be at the expense of agriculture overall, but in those parts of central and northern China where all the water is now spoken for, the farm is the only place where it can come from.

Although projections of the future diversion of irrigation water to residential and industrial uses do not yet exist for China, World Bank calculations for South Korea, a relatively well watered country, give some sense of what might lie ahead. The Bank's analysts calculate that if the Korean economy grows at an average 5.5 percent annually until 2025, growth in water withdrawals for residential and industrial use will reduce the supply available for agriculture from 13 to 7 billion tons. Ignoring the potential for reusing industrial or domestic water in agriculture, or the effect of price changes, this would reduce the water available for irrigation by nearly half. If so, the losses in the North China region, which has far less water per person to begin with, could follow a similar pattern. Such diversion would profoundly alter China's food prospect—affecting it even more than will the conversion of cropland to nonfarm uses, long a matter of concern in Beijing.

Restructuring China's Water Economy

When smaller countries such as Israel, Jordan, and Saudi Arabia have faced acute water scarcity they have simply diverted irrigation water to the cities as needed, sacrificing grain production and importing 75 to 95 percent of their grain. But China is too big to do this—it would put impossible demands on the world market—and thus must fashion an indigenous solution to the problem of water scarcity.

To do so will require restructuring the entire agricultural, energy, and industrial economies to make them more water efficient. This will entail shifting to reliance on more water-efficient crops and livestock products and on less water-intensive energy sources. It will also mean reducing pollution so that water does not become unusable for irrigation.

On the supply side, three proposals have been made for diverting water from the South, but none would provide more than 20 billion tons of water—only a drop in the bucket compared with the emerging deficits in the North. One, the so-called "western" route, calls for diverting water from the upper reach of the Yangtze to the upper reach of the Yellow River. A "middle" route has water being diverted from the northernmost point of the Han Shui River, a Yangtze tributary, directly to Beijing. The third, or "eastern" route, would divert water from the Yangtze as it approaches Shanghai, sending it north to Tianjin, the large industrial city located roughly 120 miles from Beijing (see map, pages 14 and 15).

Diverting water from the Yangtze tributary, the Han Shui, to Beijing would be comparable in reach to turning to the Mississippi River to satisfy the needs of Washington, DC. Cost estimates soar into the tens of billions of dollars. Some analysts point out that money spent on South-to-North water diversion projects could be spent much more profitably on investing in water efficiency or importing grain. Those urging the latter point out that importing 20 million tons of grain per year (Canada's annual grain exports) to North China would free up the 20 billion tons of water that would be diverted by the Han Shui scheme, but at a much lower cost.

One of the most frequently proposed responses to water scarcity is water pricing—charging users enough for water to ensure that it is used efficiently. Unfortunately, to set a price on water high enough to ensure efficient *industrial* use would put the price many times higher than farmers could afford to pay for irrigation. To ensure efficient *agricultural* use, the price of water needs to be raised, but not to the point where it becomes too expensive for farmers to use. This suggests the need for a two-tiered pricing system, with one price for farmers and another for industry and cities.

On the farmers' tier, higher prices would encourage shifting to efficiency-enhancing irrigation practices. For example, Worldwatch senior fellow Sandra Postel notes in her book *Last Oasis* that there is a great untapped potential for the use of sprinklers, which can substantially boost efficiency over the traditional flood or furrow irrigation now used on over 95 percent of China's irrigated land. One system, known as Low Energy Precision Application (LEPA), operates at low pressure with two efficiency advantages over other sprinkler designs: it uses less energy, and water is delivered close to the ground rather than sprayed into the air with high evaporation losses. Throughout the southern Great Plains of the United States, LEPA has helped farmers cope with cutbacks in water availability from aquifer depletion while at the same time lowering energy costs and boosting yields. Drip irrigation, a technology pioneered in Israel, is not economical for use on grain, but on high-value fruit and vegetable crops it can cut water use by up to 70 percent.

Along with more water-efficient agricultural techniques, there is need for shifting to less water-intensive crops. This may mean producing less rice and more wheat in some regions. With livestock products, it means raising more poultry and less pork, since a kilogram of poultry requires only half as much grain, and therefore only half as much water, as a kilogram of pork. And it may mean an official policy of discouraging consumption of livestock products in the more affluent segments of Chinese society, where animal fat intake has already reached health-damaging levels.

Another promising possibility is to increase water use efficiency in homes and industry. For example, it might well make economic sense for cities in water-scarce regions of China to introduce composting toilets rather than the traditional water-flush toilets. The Western water-intensive sewage disposal model simply may not be appropriate for water-scarce China. Beyond this, the adoption of water-efficient standards for household faucets and showers can also help stretch scarce water supplies.

As new cities rise throughout China and older cities expand and are rebuilt, urban planners would do well to keep the streams of industrial and residential wastewater separate—as opposed to replicating the Western model which combines these flows. Uncontaminated by industrial pollutants, residential wastewater can be recycled, while nutrients are removed for use as fertilizer. The present rush of expansion, while environmentally damaging and difficult to manage, at least offers a unique window of opportunity for efficient design, because poor designs adopted now will incur the economic costs of future retrofits and the social costs of water shortages.

The potential for saving water in industry is perhaps even more promising. For example, the amount of water used to produce a ton of steel in China ranges from 23 to 56 cubic meters, whereas in the highly industrialized countries, such as the United States, Japan, and Germany, the average is less than 6 cubic meters. Similarly, a ton of paper produced in China typically requires at least 450 cubic meters of water, whereas in industrial countries, it generally requires less than 200 cubic meters. For some industries, achieving high efficiency will require investing in entirely new technologies and factories. In other cases, rather modest changes in manufacturing processes can yield large water savings.

In the energy industry, fundamental restructuring is already a global imperative because of the need for climate stabilization. Fortunately, the technologies that offer the most immediate environmental benefits from the standpoint of greenhouse gas reduction—wind and solar power—are also water-efficient; they use much less water than hydropower, nuclear power or coal. Developing wind-power resources would also strengthen the economies of the wind-rich interior provinces.

Clearly, an across-the-board effort to restructure China's water economy is needed. In contrast to the traditional supply-side solutions to water scarcity—often involving gargantuan feats of engineering with adverse social and environmental effects—demand-side management is central to meeting future water needs. Just as incremental increases in per capita water use for China's huge population can lead to enormous additional water requirements, incremental gains in per capita water efficiency can lead to enormous savings of water. These efforts are not likely to prevent shrinking of irrigation water supplies in North China as aquifers are depleted and as irrigation water is diverted to cities, but they can mitigate the impact of such shrinking.

China's Grain Imports

When the expanding demand for water collides with the physical limits of supply, and household water needs can be satisfied only by diverting water from irrigation, countries typically import grain to offset the resulting production losses. In effect, to import a ton of wheat is to import a thousand tons of water. If the most efficient way for water-deficit countries to import water is in the form of grain, then water scarcity can be expected to spread across national boundaries through grain trade.

Experience elsewhere shows how water scarcity can raise dependence on imports. The world's fastest growing grain market is not East Asia, but North Africa and the Middle East, the region stretching from Morocco eastward through the Middle East to include Iran. In this region where demand for grain is fueled by rapid population growth and rising affluence, often driven by oil wealth, farmers are now so hamstrung by water scarcity that they simply cannot expand production fast enough to keep up. In 1997, this region, which contains only five percent of the world's people, accounted for roughly one-fourth of world grain imports. The water required to produce the grain imported into the region was roughly equal to the annual flow of the Nile

If China is facing ever-growing water deficits in agriculture, then it is also facing a growing gap between its rapidly rising demand for food and the ability of farmers to expand production. If the NIC projections of the need to import 175 million tons in 2025 is extrapolated to the year 2030 to mesh with our projected time horizon, it goes over 200 million tons—the equivalent of total world grain exports today.

With the scope of its analysis limited to China, the NIC study simply assumes that the needed 175 million tons of grain imports will be readily available from exporting countries, but the trends in the principal exporters—the United States, Canada, Australia, Argentina, and the European Union—raise doubts about this assumption. These countries, which produce 85 percent of the world's grain exports, steadily increased their exports from less than 60 million tons in 1960 to 200 million tons by 1980. But since 1980, there has been no growth in world grain exports even though the United States has returned to production all the cropland idled under its farm commodity programs (see Figure 2). The global total has fluctuated around 200 million tons per year for nearly two decades, initially because demand was not growing, but more recently because of an inability to produce more for export.

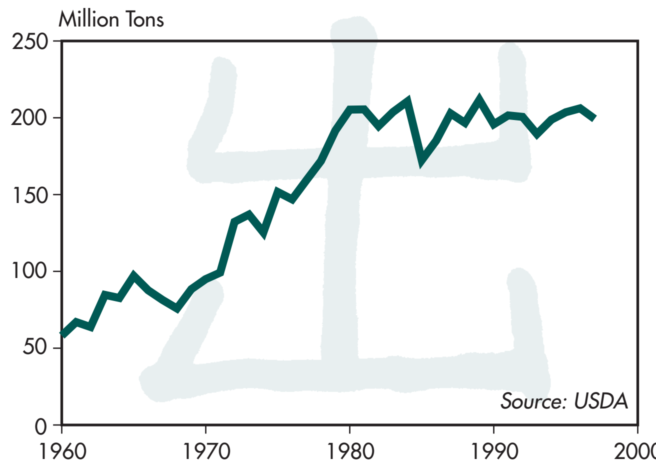


Figure 2: Grain Exports (Argentina, Australia, Canada, European Union, United States), 1960–97

In the United States, where the cropland base is essentially fixed, growth in the grain harvest is limited to the rise in land productivity. With this rise now barely keeping up with the growth in U.S. population, there is no growth in exportable supplies. The European Union, which briefly held some land out of use in the mid-1990s, had returned most of it to use by 1997. Australia and Canada, both heavily dependent on dryland farming, are constrained in their capacity to increase exports by low rainfall. Argentina can substantially expand its exports, perhaps by half or more, but it is a relatively small country, exporting under 20 million tons per year. With little potential for this group to boost exports, China's water scarcity could soon become the world's grain scarcity.

The question of whether or not these exports will be available has become a matter of acute concern for the low-income developing countries that already depend on grain imports to feed their growing populations. While China can afford to pay the elevated prices in a tight global grain market, even a modest rise in prices could—in some other, less affluent, countries—drain precious foreign exchange, boost local food prices, and trigger food riots.

Resolving the increasingly thorny political issues associated with water use and reallocation poses a challenge for the leaders in Beijing. Among these issues are the growing competition between the countryside and cities for available water supplies, interprovincial conflicts between upstream and downstream water users, and the conflict between using water to create jobs and using it to maintain food self-sufficiency. More immediately, Beijing faces a choice: investing tens of billions of dollars to move 20 billion cubic meters of water per year from the South to the North versus diverting that water from agriculture to other uses in the north and importing the 20 million tons of grain that would otherwise be produced. Few issues will so pervade a country's political life as water scarcity will that of China in the decades ahead.

As we look back, it is pertinent to ask why we did not see this pressure on China's water resources coming sooner. In 1980, when China had roughly 1 billion people and the economic reforms were just getting underway, water supplies were generally sufficient to satisfy all needs. But as we look to the year 2030, when there will be not 1 billion poor Chinese but 1.5 billion rather affluent Chinese, we see a country that will need perhaps three times as much water to fully satisfy its demand. That water is not available. China's experience illustrates for all countries the importance of stabilizing population size soon enough to allow for gains in per capita consumption within the limits of their resource base.

The NIC study recommends establishment of a permanent U.S.-China agricultural forum to develop complementary agricultural strategies and to share technology in such areas as production and irrigation efficiency. We concur with that recommendation. If the world's two leading food producers can work closely together to protect their agricultural resource bases, while the world works to stabilize population, it will benefit not only each of those countries, but the rest of the world as well.

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For Additional Information

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