I

A Civilization in Trouble

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Emerging Water Shortages

The world is incurring a vast water deficit—one that is largely invisible, historically recent, and growing fast. Because the impending water crunch usually takes the form of aquifer overpumping and falling water tables, it is often not apparent. Unlike burning forests or invading sand dunes, falling water tables cannot be readily photographed. They are often discovered only when wells go dry.

Newspapers carry frequent accounts of rivers failing to reach the sea, or lakes disappearing, or wells going dry, but these stories typically describe local situations. It is not until we begin to compile the numerous national studies—such as a 748-page analysis of the water situation in China, a World Bank study of the water situation in Yemen, or a detailed U.S. Department of Agriculture (USDA) assessment of the irrigation prospect in the western United States—that the extent of emerging water shortages worldwide can be grasped.[1]

The world water deficit is recent—a product of the tripling of water demand over the last half-century and the worldwide spread of powerful diesel and electrically driven pumps. The drilling of millions of wells has pushed water withdrawals beyond the recharge of many aquifers. The failure of governments to limit pumping to the sustainable yield of aquifers means that water tables are now falling in scores of countries. The mining of groundwater is quite literally undermining the future of some countries.[2]

Rivers running dry are far more visible. Among the rivers that now fail to reach the sea all or part of the time are the Colorado, the major river in the southwestern United States; the Yellow River, the cradle of Chinese civilization; and the Amu Darya, one of the two rivers that feed the Aral Sea in Central Asia. Other major rivers that have been reduced to a trickle when they reach the sea include the Nile, the Indus, and the Ganges.[3]

Water shortages are generating conflicts between upstream and downstream claimants, both within and among countries. For the Yellow River, the competition is between impoverished upstream provinces and more prosperous coastal provinces. For the Nile, competition is among countries, principally Egypt, the Sudan, and Ethiopia, where much of the Nile's flow originates.[4]

Water scarcity, once a local issue, is now crossing international boundaries via the international grain trade. Countries that are pressing against the limits of their water supply typically satisfy the growing need of cities and industry by diverting irrigation water from agriculture, then importing grain to offset the loss of productive capacity. Because it takes 1,000 tons of water (1,000 cubic meters) to produce 1 ton of grain, importing grain is the most efficient way to import water. Countries are now satisfying their growing demand for water by tapping international grain markets. As water shortages intensify, so too will the competition for grain in these markets. In a sense, to trade in grain futures is to trade in water futures.[5]

The link between water and food is a strong one. Our

individual daily water requirements for drinking average 4 liters per day, while the water required to produce our food each day totals at least 2,000 liters—500 times as much. In affluent societies, where grain is consumed in the form of livestock products, water consumed as food can easily reach 4,000 liters daily.[6]

Worldwide, 70 percent of all the water diverted from rivers or pumped from underground is used for irrigation. Twenty percent is used by industry and 10 percent for residential purposes. With the demand for water growing steadily in all three sectors, competition is intensifying. In this struggle for water, farmers almost always lose to cities and industry.[7]

Falling Water Tables

Scores of countries are overpumping aquifers as they struggle to satisfy their growing water needs, including each of the big three grain-producing countries—China, India, and the United States. Their populations, along with those of other countries where overpumping will measurably reduce the food supply when aquifers are depleted, exceed 3 billion people, or half the world total. (See Table 2–1.)[8]

As noted in Chapter 1, falling water tables are already affecting harvests in some countries, including China, the world's largest grain producer. A little-noticed groundwater survey released in Beijing in August 2001 revealed that the water table under the North China Plain, which produces over half of China's wheat and a third of its corn, is falling faster than earlier reported. Overpumping has largely depleted the shallow aquifer, reducing the amount of water that can be pumped from it to the annual recharge from precipitation. This is forcing well drillers to turn to the region's deep aquifer, which, unfortunately, is not replenishable.[9]

Table 2–1. *Countries with Extensive Overpumping of Aquifers in 2002*

Country	Population
	(million)
China	1,295
India	1,050
United States	291
Pakistan	150
Mexico	102
Iran	68
South Korea	47
Morocco	30
Saudi Arabia	24
Yemen	19
Syria	17
Tunisia	10
Israel	6
Jordan	5
Total	3,114

Source: See endnote 8.

The survey, conducted by the Geological Environmental Monitoring Institute (GEMI) in Beijing, reported that under Hebei Province in the heart of the North China Plain, the average level of the deep aquifer dropped 2.9 meters (nearly 10 feet) in 2000. Around some cities in the province, it fell by 6 meters. He Qingcheng, head of the GEMI groundwater monitoring team, notes that as the deep aquifer under the North China Plain is depleted, the region is losing its last water reserve—its only safety cushion.[10]

His concerns are mirrored in a World Bank report:

"Anecdotal evidence suggests that deep wells [drilled] around Beijing now have to reach 1,000 meters [more than half a mile] to tap fresh water, adding dramatically to the cost of supply." In unusually strong language for a Bank report, it foresees "catastrophic consequences for future generations" unless water use and supply can quickly be brought back into balance.[11]

The U.S. embassy in Beijing reports that wheat farmers in some areas are now pumping from a depth of 300 meters, or nearly 1,000 feet. Pumping water from this far down translates into exorbitant costs and reduced profit margins that often force farmers to abandon irrigation and return to less productive dryland farming.[12]

Falling water tables, combined with reduced government grain support prices and the loss of farm labor in provinces that are rapidly industrializing, are shrinking China's grain harvest. The wheat crop, grown mostly in arid northern China, is particularly vulnerable to water shortages. After peaking at 123 million tons in 1997, the wheat harvest has fallen in five of the last six years, coming in at 87 million tons in 2003, a drop of nearly 30 percent.[13]

The U.S. embassy in Beijing also reports that the recent decline in rice production is partly the result of water shortages. After peaking at 140 million tons in 1997, the harvest has dropped in each of the five years since then, falling to an estimated 121 million tons in 2003. Only corn, China's third major grain, has thus far avoided a decline. This is because corn prices are stronger and because the corn crop is not as dependent on irrigation water as wheat and rice are.[14]

Overall, China's grain production has fallen from its historical peak of 392 million tons in 1998 to an estimated 338 million tons in 2003. (See Figure 2–1). For perspective, this drop of over 50 million tons is equal to the Canadian grain harvest. Thus far, China has covered the

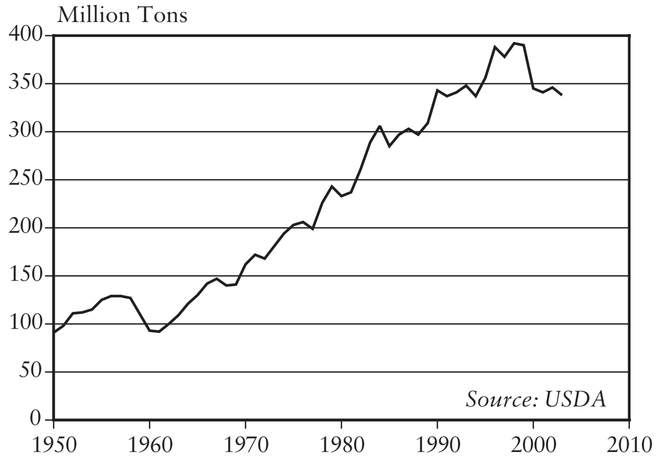

Figure 2–1. *Total Grain Production in China, 1950–2003*

fall in production by drawing down its once vast stocks, but it can only do that for one or two more years. Then it will have to turn to the world market for imports. When it does so, we likely will see the effects in higher food prices at the supermarket checkout counter.[15]

A World Bank study indicates that China is overpumping three river basins in the north by 37 billion tons—the Hai, which flows through Beijing and Tianjin; the Yellow; and the Huai, the next river south of the Yellow. At 1,000 tons of water per ton of grain, this would produce 37 million tons of grain, enough to feed 111 million Chinese.[16]

The other country with extensive overpumping is India, which is depleting aquifers in Punjab (the country's breadbasket), Haryana, Gujarat, Rajasthan, Andhra Pradesh, and Tamil Nadu. The International Water Management Institute estimates that aquifer depletion could eventually reduce India's grain harvest by one fourth.[17]

The latest data indicate that under Punjab and Haryana, water tables are falling by up to a meter a year.

Data for monitored wells in northern Gujarat suggest that the water table has fallen from a depth of 15 meters to 400 meters over the last three decades. At this point, the harvests of wheat and rice, India's principal food grains, are still increasing. But within the next few years, the loss of irrigation water could override technological progress and start shrinking the harvest, as it is already doing in China.[18]

In the United States, the USDA reports that in parts of Texas, Oklahoma, and Kansas—three leading grain-producing states—the underground water table has dropped by more than 30 meters (100 feet). As a result, wells have gone dry on thousands of farms in the southern Great Plains.[19]

Irrigated land accounts for about four fifths of the grain harvest in China and close to three fifths in India, but only one fifth in the United States. Of the leading grain producers, only China is currently experiencing a substantial decline in production. Even with a worldwide grain crunch and climbing grain prices providing an incentive to boost production, it would be difficult for China to regain earlier grain production levels given the loss of irrigation water. India can probably still expand its harvest somewhat before water shortages overwhelm the gains in production from advances in technology. For the United States, the ongoing irrigation water loss from aquifer depletion and diversion to cities does not appear to be large enough to reduce the grain harvest, but it will slow its growth.[20]

Pakistan, a country with 150 million people and growing by 4 million per year, is also overpumping its aquifers. In the Pakistani part of the fertile Punjab plain, the drop in water tables appears to be similar to that in India. Observation wells near the twin cities of Islamabad and Rawalpindi show a fall in the water table from 1982 to 2000 ranging from 1 to nearly 2 meters a year.[21]

In the province of Baluchistan, a more arid region, water tables around the provincial capital of Quetta are falling by 3.5 meters per year. Richard Garstang, a water expert with the World Wildlife Fund and a participant in a study of Pakistan's water situation, says that "within 15 years Quetta will run out of water if the current consumption rate continues."[22]

Future irrigation water cutbacks as a result of aquifer depletion will undoubtedly reduce Pakistan's grain harvest. In Pakistan, as in India, the harvest of wheat—the principal food staple—is continuing to grow, but more slowly.

Water shortages are common in Middle Eastern countries. Iran, a country of 68 million people, is overpumping its aquifers by an average of 5 billion tons per year, enough to produce one third of its annual grain harvest. Under the small but agriculturally rich Chenaran Plain in northeastern Iran, the water table was falling by 2.8 meters a year in the late 1990s. But, in 2001, the cumulative effect of a three-year drought and the new wells being drilled both for irrigation and to supply the nearby city of Mashad dropped the aquifer by an extraordinary 8 meters. Villages in eastern Iran are being abandoned as wells go dry, generating a flow of "water refugees."[23]

Saudi Arabia, a country of 24 million people, is as water-poor as it is oil-rich. It has tried to develop an extensive irrigated agriculture based largely on deep fossil aquifers. After several years of using oil money to support the price of wheat at five times the world market level to encourage farmers to develop an irrigated agriculture based on deep pumping, the government was forced to face fiscal reality and cut back on the program. Craig Smith writes in the *New York Times*, "From the air, the circular wheat fields of this arid land's breadbasket look like forest green poker chips strewn across the brown desert. But they are outnumbered by the ghostly

silhouettes of fields left to fade back into the sand, places where the kingdom's gamble on agriculture has sucked precious aquifers dry." In some areas, farmers are now pumping water from 4,000-foot-deep wells—in other words, from nearly four fifths of a mile down.[24]

A 1984 Saudi national survey reports fossil water reserves at 462 billion tons. Half of that, Smith reports, has probably disappeared by now. This suggests that irrigated agriculture could last for another decade or so and then will largely disappear, limited to the small area that can be irrigated with water from the shallow aquifers that are replenished by the kingdom's sparse rainfall. The lush fields of thirsty alfalfa, grown to feed a recently created modern dairy industry, will also become history.[25]

In Yemen, a country of 19 million, the water table under most of the country is falling by roughly 2 meters a year as water use far exceeds the sustainable yield of aquifers. In the Sana'a basin in western Yemen, the estimated annual water extraction of 224 million tons exceeds the annual recharge of 42 million tons by a factor of five, dropping the water table by 6 meters per year. Projections by the World Bank indicate the Sana'a basin, home of the national capital and 2 million people, will be pumped dry by 2010. In the search for water, the Yemeni government has drilled test wells in the basin that are 2 kilometers (1.2 miles) deep—depths normally associated with the oil industry—but they have failed to find water. Yemen must soon decide whether to bring water to Sana'a, possibly by pipeline from coastal desalting plants, if it can afford it, or to relocate the capital. Either alternative will be costly and potentially traumatic.[26]

With its population growing at a near-record 3.5 percent a year and with water tables falling everywhere, Yemen is fast becoming a hydrological basket case. Aside from the effect of overpumping on the capital, World

Bank official Christopher Ward observes that "groundwater is being mined at such a rate that parts of the rural economy could disappear within a generation."[27]

Israel, a pioneer in raising irrigation water productivity, is depleting its two principal aquifers—the coastal aquifer and the mountain aquifer that it shares with the Palestinians. Conflicts between Israelis and Palestinians over the allocation of water in the latter are ongoing. Because of severe water shortages, Israel recently discontinued the irrigation of wheat.[28]

In Mexico—home to a population of 102 million that is projected to reach 140 million by 2050—the demand for water is outstripping supply. Mexico City's water problems are legendary. Rural areas are also suffering. For example, in the agricultural state of Guanajuato, the water table is falling by 2 meters or more a year. At the national level, 51 percent of all the water extracted from underground is coming from aquifers that are being overpumped.[29]

There are two types of aquifers: replenishable and nonreplenishable (fossil) aquifers. Most of the aquifers in India and the shallow aquifer under the North China Plain are replenishable. When a replenishable aquifer is depleted, the maximum rate of pumping is necessarily reduced to the rate of recharge.

For fossil aquifers, such as the vast Ogallala under the Great Plains of the United States, the deep aquifer under the North China Plain, or the aquifer under Saudi Arabia, depletion brings pumping to an end. Farmers who lose their irrigation water have the option of returning to lower-yield dryland farming if rainfall permits. In desert situations, however, such as the southwestern United States or the Middle East, the loss of irrigation water means the end of agriculture.

The overpumping of aquifers is occurring in many countries more or less simultaneously. This means that

the depletion of aquifers and the resulting harvest cutbacks will come in many countries at roughly the same time. And the accelerating depletion of aquifers means this day may come sooner than expected, creating a potentially unmanageable situation of food scarcity.

Rivers Running Dry

As the world's demand for water has tripled over the last half-century and as the demand for hydroelectric power has grown even faster, dams and diversions of river water have drained many rivers dry. As water tables have fallen, the springs that feed rivers have gone dry, leading to the disappearance of some rivers.

As noted earlier, the Colorado, the major river in the southwestern United States, now rarely makes it to the sea. With the states of Colorado, Utah, Arizona, Nevada, and, most important, California, depending heavily on the Colorado's water, the river is simply drained dry before it reaches the Gulf of California. This excessive demand for water destroys the river's ecosystem, including, of course, its fisheries.[30]

Dams on rivers are built for irrigation, to generate electricity, and to supply water to cities and industry. Since 1950, the number of large dams, those over 15 meters high, has increased from 5,000 to 40,000. Each dam deprives a river of some of its flow. Engineers like to say that dams built to generate electricity do not take water from the river, only its energy, but this is not entirely true since reservoirs increase evaporation. The annual loss of water in arid or semiarid regions, where evaporation rates are high, is typically equal to 10 percent of the reservoir's storage capacity.[31]

The loss of river flow can affect the health of estuaries and of inland lakes and seas. The Helmand River, which originates in the mountains of eastern

Afghanistan, flows westward across the country and into Iran, where it empties into Lake Hamoun. When the Taliban built a new dam on the Helmand during the late 1990s, in violation of a water-sharing agreement between the two countries, they effectively removed all the remaining water. As a result, Lake Hamoun, which once covered 4,000 square kilometers, is now a dry lakebed. The abandoned fishing villages on its shores are being covered by sand dunes coming from the lakebed itself.[32]

A similar situation exists with the Aral Sea. The Amu Darya—which, along with the Syr Darya, feeds the Aral Sea—is now drained dry by Uzbek and Turkmen cotton farmers upstream. With the flow of the Amu Darya now cut off, only the diminished flow of the Syr Darya keeps the Aral Sea from disappearing entirely.[33]

Over the last few decades, the Aral Sea has shrunk some 58 percent in area and has lost 83 percent of its volume of water. The loss of freshwater recharge and the sea's shrinkage have led to a dramatic rise in salt levels and the demise of its rich fisheries. In addition to sandstorms, the region also now suffers from salt storms, which arise from the exposed seabed.[34]

China's Yellow River, which flows some 4,000 kilometers through five provinces before it reaches the Yellow Sea, has been under mounting pressure for several decades. It first ran dry in 1972, and since 1985 it has failed to reach the sea for part of almost every year.[35]

The Nile, the site of another ancient civilization, now barely makes it to the sea. Sandra Postel, in *Pillar of Sand*, notes that before the Aswan Dam was built some 32 billion cubic meters of water reached the Mediterranean each year. After the dam was built, however, and irrigation and other demands on the river increased, the Nile's discharge declined to less than 2 billion cubic meters.[36]

Pakistan, like Egypt, is essentially a river-based civi-

lization. The Indus not only provides surface water, it also recharges aquifers that supply the thousands of irrigation wells that now dot the Pakistani countryside. But it, too, is starting to run dry in its lower reaches.[37]

In Southeast Asia, the flow of the Mekong is being reduced by the dams being built on its upper reaches by the Chinese. The downstream countries, including Cambodia, Laos, Thailand, and Viet Nam—countries with 160 million people—complain about the reduced flow of the Mekong, but this has done little to curb China's efforts to exploit the power and the water in the river.[38]

A similar situation exists with the Tigris and Euphrates rivers, which originate in Turkey and flow into Syria and Iraq en route to the Persian Gulf. This river system, the site of Sumer and other early civilizations, is being used at near capacity. Large dams erected in Turkey and Iraq have reduced water flow to the once "fertile crescent," helping to destroy more than 90 percent of the formerly vast wetlands that enriched the delta region.[39]

Many of the river systems just discussed are described by hydrologists as "closed basins"—that is, virtually all the water in the basin is being used. If one party gets more water, other parties will get less. In most cases, this means that as urban and industrial needs rise, there is less available for irrigation.

Farmers Losing to Cities

In the competition for water among agriculture, cities, and industry, the economics of water use do not favor farmers, simply because it takes so much water to produce food. For example, while it takes 1,000 tons of water to grow a ton of wheat, it takes only 14 tons to make a ton of steel. In China, where water scarcity is a national security issue, 1,000 tons of water can be used either to produce 1 ton of wheat worth, at most, $200, or to expand industrial output by $14,000—70 times as much. In a country preoccupied with expanding the economy and creating jobs, the policy decision to make agriculture the residual claimant comes as no surprise.[40]

Many of the world's largest cities are located in closed basins. Cities in these watersheds, such as Mexico City, Los Angeles, Cairo, and Beijing, can increase their water consumption only by importing water from other basins or taking it from agriculture.

In a world of water scarcity, literally hundreds of cities are now taking water from agriculture. Among the U.S. cities that are likely to satisfy future growth in water demands by taking irrigation water from farmers are San Diego, Los Angeles, Las Vegas, Denver, and El Paso. A USDA study of 11 western states for 1996 and 1997 found that during these two years, annual sales of water rights averaged 1.65 billion tons or roughly 1 percent of the underground water used for irrigation nationwide.[41]

When the federal government reduced the flow of Colorado River water into California by 765 million tons on January 1, 2003, in accordance with a longstanding agreement that allocated the river's water among several states, it immediately set off a flurry of urban water purchases from farmers in California, including a 120-million-ton water purchase from the Sacramento Valley Irrigation District by San Diego's Municipal Water District. This purchase meant that farmers would idle riceland, reducing rice production by an estimated 120,000 tons or 3 percent of U.S. consumption.[42]

Literally hundreds of cities in other countries are meeting their growing water needs by taking some of the water that farmers count on. In western Turkey, for example, Ismir now relies heavily on well fields from the neighboring agricultural district of Manisa.[43]

Although reliable projections of rural-urban transfers

do not yet exist for many countries, World Bank calculations for South Korea, a relatively well watered country, indicate that growth in residential and industrial water use there could reduce the supply available for agriculture from 13 billion tons at present to 7 billion tons in 2025.[44]

Between 2000 and 2010, the World Bank projects that China's urban water demand will increase from 50 billion cubic meters (50 billion tons) to 80 billion, a growth of 60 percent as the country's population is projected to grow by 90 million. Industrial water demand, meanwhile, will go from 127 billion cubic meters to 206 billion, up 62 percent. Several hundred cities are looking to the countryside to satisfy their future water needs. In the region around Beijing, this shift has been under way since 1994, when farmers were banned from the reservoirs that supplied the city.[45]

As China attempts to accelerate the economic development of the upper Yellow River basin, emerging industries upstream get priority in the use of water. And as more water is used upstream, less reaches farmers downstream. In most recent years, the Yellow River not only has failed to reach the sea for part of the year, but sometimes it has failed to reach Shandong, the last province that it flows through en route to the sea.[46]

Farmers in Shandong have traditionally received roughly half of their irrigation water from the Yellow River and half from wells. Now they are losing water from both sources as the downstream river flow shrinks and as overpumping depletes local aquifers. Losses of irrigation water in a province that produces a fifth of China's corn and a seventh of its wheat help explain why China's grain production is declining. As a supplier of grain, Shandong is more important to China than Iowa and Kansas together are to the United States.[47]

Although there is no worldwide monitoring system for the diversion of irrigation water to cities and industry, the trend is clear. Slowly but surely cities are siphoning water from agriculture even as the world's farmers try to feed 70 million more people each year.[48]

Scarcity Crossing National Borders

Historically water scarcity was a local issue. It was up to national governments to balance the supply of and demand for water. Now this is changing as scarcity crosses national boundaries via the international grain trade. One of the consequences of economic globalization is that water scarcity anywhere can affect people everywhere.

The Middle East and North Africa—from Morocco in the west through Iran in the east—has emerged as the world's fastest-growing grain import market. Virtually every country in the region is pressing against the limits of its water supply. In this situation, the growing demand for water in cities and industry can be satisfied only by taking irrigation water from agriculture.

Iran and Egypt, each with some 70 million people, have become leading importers of wheat, in recent years vying with Japan—traditionally the leading wheat importer—for the top spot. Both countries now import 40 percent of their total grain supply.[49]

Algeria, with 31 million people, imports some 75 percent of its grain, which means that the water used to produce the imported grain exceeds water consumption from domestic sources. Because of its heavy dependence on imports, Algeria is particularly vulnerable to disruptions, such as grain export embargoes.[50]

It is often said that future wars in the Middle East will more likely be fought over water than over oil, but the competition for water is taking place in world grain markets. It is the countries that are financially the strongest, not necessarily those that are militarily the strongest, that are likely to fare best in this competition.

If we want to know where grain import needs will be concentrated tomorrow, we should look at where water deficits are developing today. Thus far, the countries importing a large share of their grain have been small or medium-sized nations. Now for the first time we are looking at fast-growing water deficits in both China and India, each with more than a billion people. As of 2002, both countries have small exportable grain surpluses, but in both cases they are based on overpumping aquifers.[51]

This situation is not likely to last much longer. Each year the gap between water consumption and the sustainable water supply widens. Each year the drop in water tables is greater than the year before. Both aquifer depletion and the diversion of water to cities will contribute to the growing irrigation water deficit and hence to a growing grain deficit in these countries.

After China and India, there is a second tier of smaller countries with large water deficits—Algeria, Egypt, Iran, Mexico, and Pakistan. Four of these already import a large share of their grain. Only Pakistan remains self-sufficient. But with a population expanding by 4 million a year, it will also likely soon turn to the world market for grain.[52]

When will the population giants turn to the world market for a large share of their grain? No one knows for sure. The diversion of water to cities, a gradual process, is likely to continue expanding for the indefinite future, given projected urbanization trends. The final depletion of aquifers could be abrupt and less predictable simply because we do not know how much water remains in many aquifers.

A Food Bubble Economy

As noted earlier, overpumping is a way of satisfying growing food demand that virtually guarantees a future drop in food production when aquifers are depleted.

Many countries are in essence creating a "food bubble economy"—one in which food production is artificially inflated by the unsustainable use of water. When a stock bubble bursts, the stocks eventually regain their value. But when a food bubble bursts, production may not regain earlier levels. With aquifer depletion, either the rate of pumping is reduced to the level of recharge, if it is a replenishable aquifer, or pumping ceases entirely, if it is a fossil aquifer.

This consequence of excessive reliance on underground water was not obvious when farmers began pumping on a large scale a few decades ago. The great advantage of pumping groundwater is that farmers can apply the water to crops precisely when it is needed, whereas surface water is released for everyone at once, whether or not that is the best time for individual farmers. Groundwater, in contrast, is also available throughout the year, including during the dry season, enabling farmers to double crop their land.

The superior productivity of pump irrigation water over surface water is evident from data collected from farms in India. Yields of foodgrains in Punjab for land irrigated from wells was 5.5 tons per hectare, while yields on land irrigated with water from canals averaged 3.2 tons per hectare. Similar data for the southern state of Andhra Pradesh also showed a strong advantage going to pumped irrigation, with foodgrain yields averaging 5.7 tons per hectare compared with 3.4 tons on land irrigated with canal water.[53]

The high productivity of irrigation based on groundwater means that the food production losses will be that much greater when the groundwater runs out. For India, where roughly half the irrigated land is watered with underground water, production losses could be steep. In the Pakistani Punjab, overpumping may be less damaging

than in India partly because Pakistan depends so heavily on surface water from the Indus River.[54]

In the United States, 37 percent of all irrigation water comes from underground; 63 percent comes from surface sources. Yet three of the top grain-producing states—Texas, Kansas, and Nebraska—each get 70–90 percent of their irrigation water from the Ogallala aquifer, which is essentially a fossil aquifer with little recharge.[55]

At what point does water scarcity translate into food scarcity? In which countries will the loss of irrigation water from aquifer depletion translate into an absolute decline in grain production? David Seckler and his colleagues at the International Water Management Institute summarize this issue well: "Many of the most populous countries of the world—China, India, Pakistan, Mexico, and nearly all the countries of the Middle East and North Africa—have literally been having a free ride over the past two or three decades by depleting their groundwater resources. The penalty of mismanagement of this valuable resource is now coming due and it is no exaggeration to say that the results could be catastrophic for these countries and, given their importance, for the world as a whole."[56]

Since irrigation water played such a central role in the tripling of the world grain harvest from 1950 to 2000, it comes as no surprise that water losses will shrink harvests. Outstanding among the countries that are living in a food bubble economy are China and India, which together contain 38 percent of the world's people. Less populous countries in a similar position are Pakistan, Mexico, and Saudi Arabia. The question for each of these countries, and for the entire world, is not whether the bubble will burst, but when.[57]