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Falling Water Tables and Shrinking Harvests

The Arab oil-export embargo of the 1970s affected more than just the oil flowing from the Middle East. The Saudis realized that since they were heavily dependent on imported grain, they were vulnerable to a grain counter-embargo. Using oil-drilling technology, they tapped into an aquifer far below the desert to produce irrigated wheat. In a matter of years, Saudi Arabia was self-sufficient in wheat, its principal staple food.[1]

But after more than 20 years of wheat self-sufficiency, the Saudis announced in January 2008 that this aquifer was largely depleted and they would be phasing out wheat production. Between 2007 and 2010, the wheat harvest of nearly 3 million tons dropped by more than two thirds. At this rate the Saudis will harvest their last wheat crop in 2012 and then will be totally dependent on imported grain to feed nearly 30 million people.[2]

The unusually rapid phaseout of wheat farming in Saudi Arabia is due to two factors. First, in this arid country there is little farming without irrigation. Second, irrigation there depends almost entirely on a fossil aquifer, which unlike most aquifers does not recharge naturally from rainfall. The desalted sea water Saudi Arabia uses to supply its cities is far too costly for irrigation use.[3]

Saudi Arabia's growing food insecurity has even led it to buy or lease land in several other countries, including two of the world's hungriest, Ethiopia and Sudan. In effect, the Saudis are planning to produce food for themselves with the land and water resources of other countries.[4]

In neighboring Yemen, replenishable aquifers are being pumped well beyond the rate of recharge, and the deeper fossil aquifers are also being rapidly depleted. As a result, water tables are falling throughout Yemen by some 2 meters per year. In the capital, Sana'a—home to 2 million people—tap water is available only once every 4 days; in Taiz, a smaller city to the south, it is once every 20 days.[5]

Yemen, with one of the world's fastest-growing populations, is becoming a hydrological basket case. With water tables falling, the grain harvest has shrunk by one third over the last 40 years, while demand has continued its steady rise. As a result, the Yemenis now import more than 80 percent of their grain. With its meager oil exports falling, with no industry to speak of, and with nearly 60 percent of its children stunted and chronically undernourished, this poorest of the Arab countries is facing a bleak future.[6]

The likely result of the depletion of Yemen's aquifers—which will lead to further shrinkage of its harvest and spreading hunger and thirst—is social collapse. Already a failing state, it may well devolve into a group of tribal fiefdoms, warring over whatever meager water resources remain. Yemen's internal conflicts could spill over its long, unguarded border with Saudi Arabia.[7]

These two countries represent extreme cases, but many other countries also face dangerous water shortages. The world is incurring a vast water deficit—one that is largely invisible, historically recent, and growing fast. Half the world's people live in countries where water tables are falling as aquifers are being depleted. And since

70 percent of world water use is for irrigation, water shortages can quickly translate into food shortages.[8]

The global water deficit is a product of the tripling of water demand over the last half-century coupled with the worldwide spread of powerful diesel and electrically driven pumps. Only since the advent of these pumps have farmers had the pumping capacity to pull water out of aquifers faster than it is replaced by precipitation.[9]

As the world demand for food has soared, millions of farmers have drilled irrigation wells to expand their harvests. In the absence of government controls, far too many wells have been drilled. As a result, water tables are falling and wells are going dry in some 20 countries, including China, India, and the United States—the three countries that together produce half the world's grain.[10]

The overpumping of aquifers for irrigation temporarily inflates food production, creating a food production bubble, one that bursts when the aquifer is depleted. Since 40 percent of the world grain harvest comes from irrigated land, the potential shrinkage of the supply of irrigation water is of great concern. Among the big three grain producers, roughly a fifth of the U.S. grain harvest comes from irrigated land. For India, the figure is three fifths and for China, roughly four fifths.[11]

There are two sources of irrigation water: underground water and surface water. Most underground water comes from aquifers that are regularly replenished with rainfall; these can be pumped indefinitely as long as water extraction does not exceed recharge. But a distinct minority of aquifers are fossil aquifers—containing water put down eons ago. Since these do not recharge, irrigation ends whenever they are pumped dry. Among the more prominent fossil aquifers are the Ogallala underlying the U.S. Great Plains, the Saudi one described earlier, and the deep aquifer under the North China Plain.[12]

Surface water, in contrast, is typically stored behind dams on rivers and then channeled onto the land through a network of irrigation canals. Historically, and most notably from 1950 until the mid-1970s, when many of the world's large dams were built, this was the main source of growth in world irrigated area. During the 1970s, however, as the sites for new dams became fewer, the growth in irrigated area shifted from building dams to drilling wells in order to gain access to underground water.[13]

Given a choice, farmers prefer having their own wells because they can control the timing and the amount delivered in a way that is not possible with large, centrally managed canal irrigation systems. Pumps let them apply water when the crop needs it, thus achieving higher yields than with large-scale, river-based irrigation systems. As world demand for grain climbed, farmers throughout the world drilled more and more irrigation wells with little concern for how many the local aquifer could support. As a result, water tables are falling and millions of irrigation wells are going dry or are on the verge of doing so.[14]

There are two rather scary dimensions of the emerging worldwide shortage of irrigation water. One is that water tables are falling in many countries at the same time. The other is that once rising water demand climbs above the recharge rate of an aquifer, the excess of demand over sustainable yield widens with each passing year. This means that the drop in the water table as a result of overpumping is also greater each year. Since growth in the demand for water is typically exponential, largely a function of population growth, the decline of the aquifer is also exponential. What starts as a barely noticeable annual drop in the water table can become a rapid fall.

The shrinkage of irrigation water supplies in the big three grain-producing countries is of particular concern.

Thus far, these countries have managed to avoid falling harvests at the national level, but continued overexploitation of aquifers could soon catch up with them. In most of the leading U.S. irrigation states, the irrigated area has peaked and begun to decline. In California, historically the irrigation leader, a combination of aquifer depletion and the diversion of irrigation water to fast-growing cities has reduced irrigated area from nearly 9 million acres in 1997 to an estimated 7.5 million acres in 2010. (One acre equals 0.4 hectares.) In Texas, the irrigated area peaked in 1978 at 7 million acres, falling to some 5 million acres as the Ogallala aquifer underlying much of the Texas panhandle was depleted.[15]

Other states with shrinking irrigated area include Arizona, Colorado, and Florida. Colorado has watched its irrigated area shrink by 15 percent over the last decade or so. Researchers there project a loss of up to 400,000 acres of irrigated land between 2000 and 2030—a drop of more than one tenth. All three states are suffering from both aquifer depletion and the diversion of irrigation water to urban centers. And now that the states that were rapidly expanding their irrigated area, such as Nebraska and Arkansas, are starting to level off, the prospects for any national growth in irrigated area have faded. With water tables falling as aquifers are depleted under the Great Plains and California's Central Valley, and with fast-growing cities in the Southwest taking more and more irrigation water, the U.S. irrigated area has likely peaked.[16]

India is facing a much more difficult situation. A World Bank study reported in 2005 that the grain supply for 175 million Indians was produced by overpumping water. This situation is widespread—with water tables falling and wells going dry in most states. These include Punjab and Haryana, two surplus grain producers that supply most of the wheat and much of the rice used in

India's massive food distribution program for low-income consumers.[17]

Up-to-date and reliable information is not always easy to get. But it is clear that overpumping is extensive, water tables are falling, wells are going dry, and farmers who can afford to are drilling ever deeper wells in what has been described as "a race to the bottom."[18]

Is India's irrigated area still expanding or has it started to shrink? Based on studies by independent researchers, there is little reason to believe that it is still expanding and ample reason to think that in India, as in the United States, decades of overpumping in key states are leading to aquifer depletion on a scale that is reducing the irrigation water supply. India's water-based food bubble may be about to burst.[19]

In China, although surface water is widely used for irrigation, the principal concern is the northern half of the country, where rainfall is low and water tables are falling everywhere. This includes the highly productive North China Plain, which stretches from just north of Shanghai to well north of Beijing and which produces half of the country's wheat and a third of its corn.[20]

Overpumping in the North China Plain suggests that some 130 million Chinese are being fed with grain produced with the unsustainable use of water. Farmers in this region are pumping from two aquifers: the so-called shallow aquifer, which is rechargeable but largely depleted, and the deep fossil aquifer. Once the latter is depleted, the irrigated agriculture dependent on it will end, forcing farmers back to rainfed farming.[21]

A little-noticed groundwater survey done a decade ago by the Geological Environment 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.[22]

In a 2010 interview with *Washington Post* reporter Steven Mufson, He Qingcheng noted that underground water now meets three fourths of Beijing's water needs. The city, he said, is drilling 1,000 feet down to reach water—five times deeper than 20 years ago. His concerns are mirrored in the unusually strong language of a World Bank report on China's water situation that foresees "catastrophic consequences for future generations" unless water use and supply can quickly be brought back into balance.[23]

Furthermore, China's water-short cities and rapidly growing industrial sector are taking an ever-greater share of the available surface and underground water resources. In many situations, growth in urban and industrial demand for water can be satisfied only by diverting water from farmers.[24]

When will China's irrigated area begin to shrink? The answer is not clear yet. Although aquifer depletion and the diversion of water to cities are threatening to reduce the irrigated area in northern China, new dams being built in the mountainous southwest may expand the irrigated area somewhat, offsetting at least some of the losses elsewhere. However, it is also possible that the irrigated area has peaked in China—and therefore in all three of the leading grain-producing countries.[25]

The geographic region where water shortages are most immediately affecting food security is the Middle East. In addition to the bursting food bubble in Saudi Arabia and the fast-deteriorating water situation in Yemen, both Syria and Iraq—the other two populous countries in the region—have water troubles. Some of these arise from the reduced flows of the Euphrates and

Tigris Rivers, which both countries depend on for irrigation water. Turkey, which controls the headwaters of these rivers, is in the midst of a massive dam building program that is slowly reducing downstream flows. Although all three countries are party to water-sharing arrangements, Turkey's ambitious plans to expand both hydropower and irrigation are being fulfilled partly at the expense of its two downstream neighbors.[26]

Given the future uncertainty of river water supplies, farmers in Syria and Iraq are drilling more wells for irrigation. This is leading to overpumping and an emerging water-based food bubble in both countries. Syria's grain harvest has fallen by one fifth since peaking at roughly 7 million tons in 2001. In Iraq, the grain harvest has fallen by one fourth since peaking at 4.5 million tons in 2002.[27]

Jordan, with 6 million people, is also on the ropes agriculturally. Forty or so years ago, it was producing over 300,000 tons of grain annually. Today it produces only 60,000 tons and thus must import over 90 percent of its grain. In this region only Lebanon has avoided a decline in grain production.[28]

In Israel, which banned the irrigation of wheat in 2000 due to water scarcity, production of grain has been falling since 1983. With a population of 7 million people, Israel now imports 98 percent of the grain it consumes.[29]

To the east, water supplies are also tightening in Iran. An estimated one fifth of its 75 million people are being fed with grain produced by overpumping. Iran has the largest food bubble in the region.[30]

Thus in the Middle East, where populations are growing fast, the world is seeing the first collision between population growth and water supply at the regional level. For the first time in history, grain production is dropping in a geographic region with nothing in sight to arrest the decline. Because of the failure of governments in the region to mesh population and water policies, each day

now brings 10,000 more people to feed and less irrigation water with which to feed them.[31]

Afghanistan, a country of 29 million people, is also faced with fast-spreading water shortages as water tables fall and wells go dry. In 2008 Sultan Mahmood Mahmoodi, a senior official in the Afghan Ministry of Water and Energy, said "our assessments indicate that due to several factors, mostly drought and excessive use, about 50 percent of groundwater sources have been lost in the past several years." The response is to drill deeper wells, but this only postpones the inevitable day of reckoning—the time when aquifers go dry and the irrigated land reverts to much less productive dryland farming. Drilling deeper treats the symptoms, not the cause, of this issue. Afghanistan, a landlocked country with a fast-growing population, is already importing a third of its grain from abroad.[32]

Thus far the countries where shrinking water resources are measurably reducing grain harvests are all ones with smaller populations. But what about the middle-sized countries such as Pakistan or Mexico, which are also overpumping their aquifers to feed growing populations?

Pakistan, struggling to remain self-sufficient in wheat, appears to be losing the battle. Its population of 185 million in 2010 is projected to reach 246 million by 2025, which means trying to feed 61 million more people in 15 years. But water levels in wells are already falling by a meter or more each year around the twin cities of Islamabad and Rawalpindi. They are also falling under the fertile Punjab plain, which Pakistan shares with India. Pakistan's two large irrigation reservoirs, Mangla and Tarbela, have lost one third of their storage capacity over the last 40 years as they have filled with silt. A World Bank report, *Pakistan's Water Economy: Running Dry*, sums up the situation: "the survival of a modern and growing Pakistan is threatened by water."[33]

In Mexico, home to 111 million people, the demand for water is outstripping supply. Mexico City's water problems are well known, but rural areas are also suffering. In the agricultural state of Guanajuato, the water table is falling by 6 feet or more a year. In the northwestern wheat-growing state of Sonora, farmers once pumped water from the Hermosillo aquifer at a depth of 40 feet. Today, they pump from over 400 feet. With 51 percent of all water extraction in Mexico from aquifers that are being overpumped, Mexico's food bubble may burst soon.[34]

In our water-scarce world, the competition between farmers and cities is intensifying. The economics of water use do not favor farmers in this struggle, simply because it takes so much water to produce food. For example, while it takes only 14 tons of water to produce a ton of steel, it takes 1,000 tons of water to produce a ton of wheat. In countries preoccupied with expanding the economy and creating jobs, agriculture becomes the residual claimant.[35]

Worldwide, roughly 70 percent of all water use is for irrigation, 20 percent goes to industry, and 10 percent goes to residential use. Cities in Asia, the Middle East, and North America are turning to farmers for water. This is strikingly evident in Chennai (formerly Madras), a city of 8 million on the east coast of India. As a result of the city government's inability to supply water to many of its residents, a thriving tank-truck industry has emerged that buys water from farmers and hauls it to the city's thirsty residents.[36]

For farmers near the city, the market price of water far exceeds the value of the crops they can produce with it. Unfortunately, the 13,000 tankers hauling water to Chennai are mining the region's underground water resources. Water tables are falling and shallow wells have gone dry. Eventually even the deeper wells will go dry, depriving

these communities of both their food supply and their livelihood.[37]

In the U.S. southern Great Plains and the Southwest, where water supplies are tight, the growing water needs of cities and thousands of small towns can be satisfied only by taking water from agriculture. A monthly publication from California, the *Water Strategist*, devotes several pages to a listing of water sales in the western United States. Scarcely a working day goes by without another sale. A University of Arizona study of over 2,000 of these water transfers from 1987 to 2005 reported that at least 8 out of 10 involved individual farmers or irrigation districts selling water to cities and municipalities.[38]

Colorado has one of the world's most active water markets. Fast-growing cities and towns in a state with high immigration are buying irrigation water rights from farmers and ranchers. In the upper Arkansas River basin, which occupies the southeastern quarter of the state, Colorado Springs and Aurora (a suburb of Denver) have already bought water rights to one third of the basin's farmland. Aurora has purchased rights to water that was once used to irrigate 23,000 acres of cropland in Colorado's Arkansas Valley.[39]

Even larger purchases are being made by cities in California. In 2003, San Diego bought annual rights to 247 million tons (200,000 acre-feet) of water from farmers in the nearby Imperial Valley—the largest farm-to-city water transfer in U.S. history. This agreement covers the next 75 years. And in 2004, the Metropolitan Water District, which supplies water to some 19 million southern Californians in several cities, negotiated the purchase of 137 million tons of water per year from farmers for the next 35 years. Without irrigation water, the highly productive land owned by these farmers is wasteland. The sellers would like to continue farming, but city officials offer far more for the water than the farmers

could possibly earn by irrigating crops.[40]

Whether it is outright government expropriation, farmers being outbid by cities, or cities simply drilling deeper wells than farmers can afford, the world's farmers are losing the water war. For them, it is all too often a shrinking share of a shrinking supply. Slowly but surely, fast-growing cities are siphoning water from the world's farmers even as they try to feed some 80 million more people each year.[41]

In countries where virtually all water is spoken for, as in North Africa and the Middle East, cities can typically get more water only by taking it from irrigation. Countries then import grain to offset the loss of grain production. Since it takes 1,000 tons of water to produce 1 ton of grain, importing grain is the most efficient way to import water. Countries are in effect using grain to balance their water books. Similarly, trading in grain futures is, in a sense, trading in water futures. To the extent that there is a world water market, it is embodied in the world grain market.[42]

How are all these pressures on water supplies affecting grain production in individual countries and worldwide? Is irrigated area expanding or shrinking? If the latter, is it shrinking fast enough to override technological gains and reduce the grain harvest in absolute terms, or will it simply slow its growth?

Today more than half of the world's people live in countries with food bubbles. The question for each of these countries is not whether its bubble will burst, but when—and how the government will cope with it. Will governments be able to import grain to offset production losses? For some countries, the bursting of the bubble may well be catastrophic. For the world as a whole, the near-simultaneous bursting of several national food bubbles as aquifers are depleted could create unmanageable food shortages.[43]

This situation poses an imminent threat to food security and political stability. We have a choice to make. We can continue with overpumping as usual and suffer the consequences. Or we can launch a worldwide effort to stabilize aquifers by raising water productivity—patterning the campaign on the highly successful effort to raise grainland productivity that was launched a half-century ago.

Data, endnotes, and additional resources can be found on Earth Policy's Web site, at www.earth-policy.org.