The Post Carbon Reader Series: Water

Water

Adapting to a New Normal

By Sandra Postel

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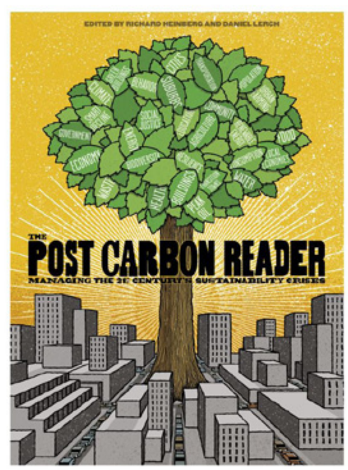

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When it comes to water, the past is no longer a reliable guide to the future.

Water, like energy, is essential to virtually every human endeavor. It is needed to grow food and fiber, to make clothes and computers, and, of course, to drink. The growing number of water shortages around the world and the possibility of these shortages leading to economic disruption, food crises, social tensions, and even war suggest that the challenges posed by water in the coming decades will rival those posed by declining oil supplies.

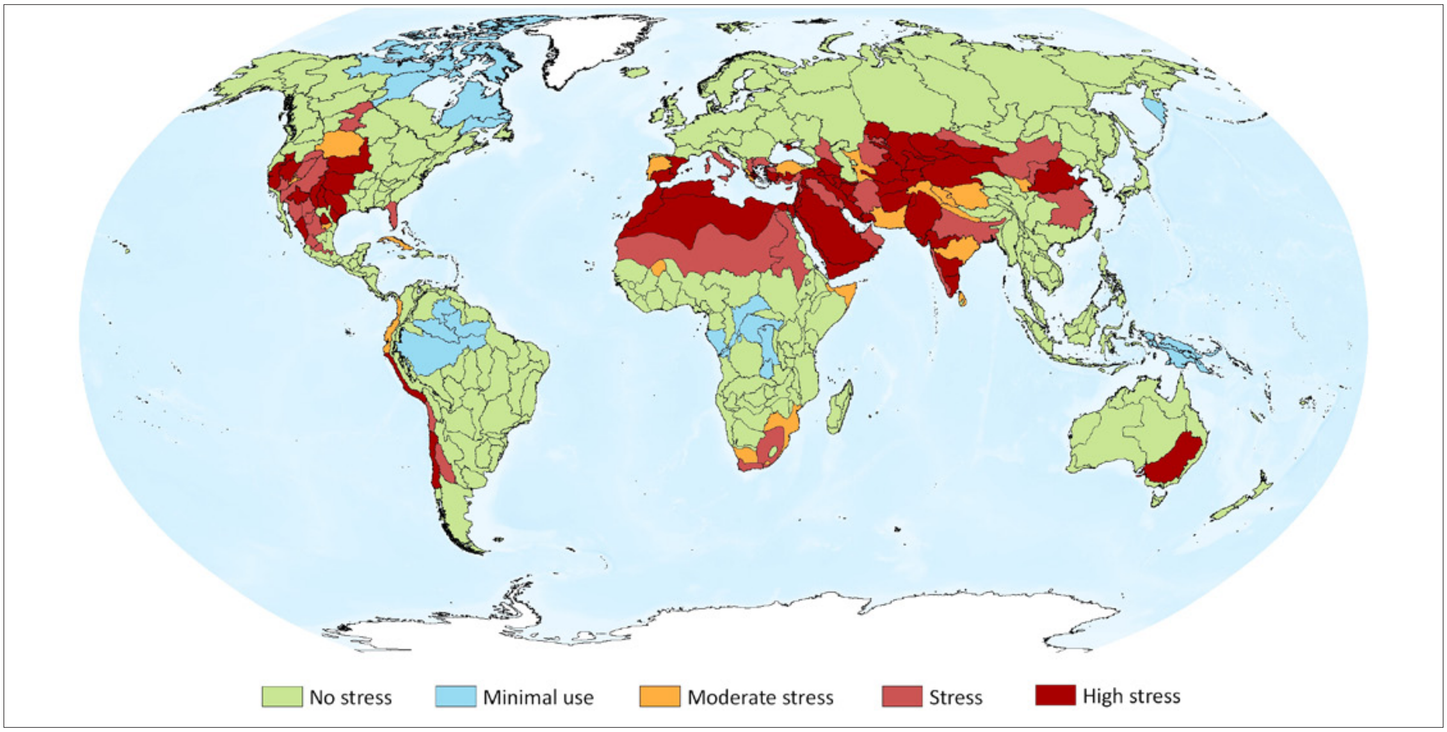
In fact, our water problem turns out to be much more worrisome than our energy situation, for three main reasons. First, unlike oil and coal, water is much more than a commodity: It is the basis of life. Deprive any plant or animal of water, and it dies. Our decisions about water—how to use, allocate, and manage it—are deeply ethical ones; they determine the survival of most of the planet's species, including our own. Second, also unlike oil and coal, water has no substitutes. The global economy is transitioning away from fossil fuels toward solar, wind, and other noncarbon energy sources, but there is no transitioning away from water. And third, it is through water that we will experience the impacts of climate change most directly.

The rise in global temperatures driven by the last 150 years of humanity's greenhouse gas emissions is fundamentally altering the cycling of water between the sea, the atmosphere, and the land. Climate scientists warn of more extreme floods and droughts and of changing precipitation patterns that will make many dry areas drier and wet areas wetter. They warn of melting glaciers and ice caps that within a few decades could severely diminish the river flows upon which nearly a third of the world's people depend.[1] As if on cue, nature seems to be highlighting these warnings at every turn:

- Floods, droughts, storms, and other climate-related natural disasters forced 20 million people from their homes in 2008.
- Australia remains locked in a decade-long drought deemed the worst in the country's 117 years of record-keeping.
- In late August 2008, India faced the dislocation of some 3 million people when the Kosi River breached a dam and roared out of the Himalayas, causing the worst flooding of that river in fifty years.
- Ten months later, India witnessed its driest June in eighty years with millions of farmers unable to plant their crops.
- In 2009, famine stalked millions in the Horn of Africa, as failed rains led to the worst food crisis in Ethiopia and Kenya in a quarter century.[2]

The United States is by no means immune to these climate-related water risks. While farmers in the Midwest continued recovering from the spring flood of 2008 (in some areas, the second "100-year flood" in fifteen years), farmers in California and Texas fallowed

FIGURE 7.1
Water Stress Areas of the World



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cropland and sent cattle prematurely to slaughter to cope with the drought of 2009. In the Southeast, after twenty months of dryness, Georgia governor Sonny Perdue stood outside the state capitol in November 2007 and led a prayer for rain, beseeching the heavens to turn on a spigot for his parched state. Two years later, Perdue was pleading instead for federal aid after intense rainstorms caused massive flooding near Atlanta that claimed at least seven lives.[3]

Although none of these disasters can be pinned directly on global warming, they are the kinds of events climate scientists warn will occur more often as the planet heats up. Even more worrisome, the effects of climate change are already calling into question the very assumptions that have underpinned water planning and management for decades. In 2008, seven top water scientists argued persuasively in the journal *Science* that "stationarity"—the foundational concept that natural systems vary and fluctuate within an unchanging set of boundaries—is no longer valid for our understanding of the global water system.[4] In other words, when it comes to water, the past is no longer a reliable guide to the future. The data and statistical tools used to plan $500 billion worth of annual global investments in dams, flood-control structures, diversion projects, and other big pieces of water infrastructure are no longer trustworthy.[5]

This is not just a problem for the planners and civil servants who run our local water systems. It raises very serious questions about community health, public safety, food security, and risk management. Will those levees keep the river within its banks? Should that expensive new dam be built when its useful life will be shortened by silt washed down from flooding mountainsides? Will farms get needed irrigation water once the glacier-fed river flows have dwindled? How do we guard against what once seemed unthinkable—the drying up of prime water sources?

In more and more regions of the world, the unthinkable seems to be close at hand. Many Australian water

Only a tiny share of all the water on Earth—less than one-hundredth of 1 percent—is fresh and renewed each year by the solar-powered hydrologic cycle.

managers now believe that a decade-long dry spell that has sent rice production plummeting, depleted reservoirs, and left the Murray River trickling into the sand is not going away. Increasingly, the question "Down Under" is not when the drought will end, but how this country of more than 21 million people—and its globally significant agricultural sector—can adapt to a permanently drier climate.[6]

In the U.S. Southwest, a similar day of reckoning is on the horizon. Scientists at the Scripps Institution of Oceanography at the University of California–San Diego estimate that there is a 50 percent chance that Lake Mead—the vast reservoir that delivers Colorado River water to tens of millions of people and one million acres of irrigated land—will dry up by 2021.[7] In 2000, Lake Mead stood at 96 percent of capacity; by the summer of 2009, it was down to 43 percent. After analyzing nineteen climate models, a team of thirteen earth scientists concluded in 2007 that the Dust Bowl-like dryness seen in the region in recent years "will become the new climatology of the American Southwest within a time frame of years to decades."[8] As in Australia, it may be folly—and a loss of precious time—to assume that business as usual and life as it's currently lived in the Southwest can continue.

The water challenges confronting us locally, regionally, and globally are unprecedented. They call for fundamental changes in how we use, manage, and even think about water. The good news is that it's within our economic and technological ability to have a future in which all food and water needs are met, healthy ecosystems are sustained, and communities remain secure and resilient in the face of changing circumstances. The path most of the world is on, however, will not lead to this more desirable state.

Where We Are, and How We Got Here

At first glance, it's hard to believe the world could be in trouble with water. Ever since the Apollo astronauts photographed Earth from space, we've had the image of our home as a strikingly blue planet, a place of great water wealth. But from a practical standpoint, this image is largely illusory. Most of Earth's water is ocean, which provides a multitude of benefits but is far too salty to drink, irrigate crops, or manufacture computer chips. Only a tiny share of all the water on Earth—less than one-hundredth of 1 percent—is fresh and renewed each year by the solar-powered hydrologic cycle.

Although renewable, freshwater is finite: The quantity available today is virtually the same as when civilizations first arose thousands of years ago. As world population grows, the volume of water available per person decreases; thus, between 1950 and 2009, as world population climbed from 2.5 billion to 6.8 billion, the global renewable water supply per person declined by

63 percent. If, as projected, world population climbs to 8 billion by 2025, the water supply per person will drop by an additional 15 percent.[9]

Though telling, these global figures mask the real story. The rain and snow falling on the land is not evenly distributed across the continents or throughout the year (see figure 7.1).[10] Many of the world's people and farms are not located where the usable water is. China, for instance, has 19.5 percent of the world's population, but only 7 percent of the renewable freshwater. The United States, by contrast, has 4.5 percent of the world's population and nearly 8 percent of the renewable freshwater. Even so, most of U.S. farm irrigation and urban growth is in the West, which has much less water than the eastern United States.

For most of modern history, water management has focused on bringing water under human control and transferring it to expanding cities, industries, and farms. Since 1950, the number of large dams has climbed from 5,000 to more than 45,000—an average construction rate of two large dams per day for half a century. Globally, 364 large water-transfer schemes move 400 billion cubic meters (1 cubic meter equals about 264 gallons) of water annually from one river basin to another—equivalent to transferring the annual flow of twenty-two Colorado Rivers. Millions of wells tap underground aquifers, using diesel or electric pumps to lift vast quantities of groundwater to the surface.[11] It's hard to fathom today's world of 6.8 billion people and $60 trillion in annual economic output without such water engineering. It has allowed oasis cities like Phoenix and Las Vegas to thrive in the desert, world food production to expand along with population, and living standards for hundreds of millions to rise.

But the benefits of water development have not been shared equitably. More than 1 billion people lack access to safe drinking water, and some 850 million people are chronically hungry. Moreover, many regions have overshot their sustainable limits of water use. An unsettling number of large rivers—including the Colorado, Rio Grande, Yellow, Indus, Ganges, Amu Darya, Murray, and Nile—are now so overtapped that they discharge little or no water to the sea for months at a time.[12] The overpumping of groundwater is causing water tables to fall across large areas of northern China, India, Pakistan, Iran, the Middle East, Mexico and the western United States. As much as 10 percent of the world's food is produced by overpumping groundwater. This creates a bubble in the food economy far more serious than the recent housing, credit, or dot-com bubbles, for we are meeting some of today's food needs with tomorrow's water.[13]

Excessive extractions for agriculture and a decade-long drought have decimated Australia's Murray-Darling river system, the continent's largest.

This overpumping is particularly serious in India. Using satellite data, scientists have recently estimated that groundwater is being depleted across northern India, which includes the nation's breadbasket, to the tune of 54 billion cubic meters per year. As wells run dry, the nation's food supply—as well as the livelihoods of the region's 114 million people—is increasingly at risk.[14] Likewise, in the United States, the massive Ogallala Aquifer is steadily being depleted. The Ogallala spans parts of eight states, from southern South Dakota to northwest Texas, and provides 30 percent of the groundwater used for irrigation in the country. As of 2005, a volume equivalent to two-thirds of the water in Lake Erie had been depleted from the

In a world of changing rainfall patterns and river flows, substantial hydrologic uncertainty, and rising energy costs, water mega-projects are risky.

Ogallala.[15] As in India, most farmers will stop irrigating when the wells run dry or the water drops so far down that it's too expensive to pump.

It is tempting to respond to these predicaments with bigger versions of the familiar solutions of the past—drill deeper wells, build bigger dams, move more river water from one place to another. Indeed, many leaders and localities are responding in just that way. By some estimates, the volume of water moved through river-transfer schemes could more than double by 2020.

China is proceeding with a massive $60 billion project to transfer water from the Yangtze River basin in the south to the water-scarce north. If completed, it would be the largest construction project on Earth, transferring 41.3 billion cubic meters of water per year—a volume equal to half the Nile River.[16] India's Interlinking Rivers Project would be even more grandiose. Estimated to cost at least $120 billion, it entails building 260 transfers between rivers with much of the water moved from northern Himalayan rivers, including the Ganges and Brahmaputra, to water-scarce western provinces. Though still in the planning stages, the main goal would be to expand the nation's irrigated area by about a third, some 35 million hectares.[17]

In a world of changing rainfall patterns and river flows, substantial hydrologic uncertainty, and rising energy costs, such mega-projects are risky. They often take decades to complete, so payback periods on the large capital investments can be very long (if full payback occurs at all). They often worsen social inequities, such as when poor people are dislocated from their homes to make way for the dams and canals and "downstream" communities lose the flows that sustained their livelihoods. And serious environmental damage—from soil salinization, water waste, altered river flows, and the loss of fisheries—routinely follows on the heels of such projects.[18] Moreover, large-scale infrastructure built to accommodate river flows today may be poorly matched to climate-altered flows of the future. The Himalayan rivers central to India's Interlinking Rivers Project, for example, will carry greatly diminished flows once the glaciers that feed them disappear.

In addition, giant water projects require giant quantities of energy. Pumping, moving, treating, and distributing water take energy at every stage. Transferring Colorado River water into southern California, for example, requires about 1.6 kilowatt-hours (kWh) of electricity per cubic meter of water; the same quantity of water sent hundreds of kilometers from north to south through California's State Water Project takes about 2.4 kWh. As a result, the energy required to provide drinking water to a typical southern California home can rank third behind that required to run the air conditioner and refrigerator.[19]

Another increasingly popular option for expanding water supplies—desalination—imposes a high energy

One of the massive canals being constructed for the South–North Water Diversion project in China.

price as well.[20] Producing 1 cubic meter (about 264 gallons) of drinkable water from saltwater through reverse osmosis requires about 2 kWh of electricity, usually produced from fossil fuels. Although that energy requirement is down from 5–10 kWh twenty years ago, it is still energy intensive. Moreover, today's most energy-efficient desalting plants are approaching the theoretical thermodynamic limit for separating salts from water, so further energy reductions will be modest at best.[21] Currently, the roughly 15,000 desalination plants worldwide have the capacity to produce 15.3 billion cubic meters of water per year, which is less than 0.5 percent of global water demand. Some 47 percent of this capacity is in the Middle East, where many nations can afford desalination—essentially turning their oil into water.[22]

Despite desalination's high costs, carbon dioxide output, risks to coastal marine environments, and production of toxic waste, global capacity roughly doubled between 1995 and 2006. Most U.S. capacity is in Florida, California, and Texas, with many more plants slated to be built.[23] Unfortunately, planners and policymakers still eyeing desalination as a silver-bullet solution to water shortages apparently miss—or dismiss—the perverse irony: By burning more fossil fuels, desalination will likely worsen the problem they are trying to solve while making local water supplies more and more dependent on increasingly expensive fossil fuels.

A Smarter Path toward Water Security

As with many challenges, finding the best solutions requires first asking the right questions. Typically, when planners and engineers see a water shortage on the horizon, they ask themselves what options exist to expand the supply. The typical answer: Get more water from a distant river, deeper wells, or a desalination plant.

But as the limitations of these "supply-side" options have become more apparent, a vanguard of citizens, communities, farmers, and corporations has started asking a different question: What do we really need the water *for*, and can we meet that need with less? The upshot of this shift in thinking is a new movement in water management that is much more about ideas, ingenuity, and ecological intelligence than it is about pumps, pipelines, dams, and canals.

This smarter path takes many forms, but it embodies two strategic attributes. First, solutions tend to work with nature, rather than against it. In this way, they make effective use of so-called ecosystem services—the benefits provided by healthy watersheds, rivers, wetlands, and other ecological systems. And second, through better technologies and more informed choices, these solutions seek to raise water productivity—the benefit derived from each liter of water extracted from a river, lake, or aquifer.

Working with nature is critically important to building resilience and reducing the energy costs associated with water delivery and use. We can think of a landscape composed of well-functioning ecosystems as "green infrastructure" that provides valuable services to society, just as roads and bridges do. Healthy rivers and watersheds, for instance, filter out pollutants, mitigate floods and droughts, recharge groundwater supplies,

There are many ways communities can work with nature to meet their water needs while reducing energy costs and building resilience.

and sustain fisheries. They do this work with free energy from the sun—no fossil fuels or manufactured energy is required. By contrast, all the technological alternatives—building and running a treatment plant to remove pollutants, artificially recharging groundwater, constructing dikes and levees, raising fish on farms—require external inputs of increasingly expensive energy.

Of course, one of the most important "services" healthy watersheds perform is the provision of clean drinking water. If a watershed is doing the work of a water treatment plant—filtering out pollutants, and at a lower cost to boot—then it often pays to protect that watershed. New York City, for instance, is investing some $1.5 billion to restore and protect the Catskills-Delaware watershed (which supplies 90 percent of its drinking water) in lieu of constructing a $6 billion filtration plant that would cost an additional $300 million a year to operate.[24] A number of other cities across the United States—from tiny Auburn, Maine, to the city of Seattle—have saved hundreds of millions of dollars in avoided capital and operating costs by opting for watershed protection over filtration plants. In doing so, they have enjoyed many other benefits, such as preserving open space, creating recreational opportunities, protecting habitat for birds and wildlife, and (by preserving trees) mitigating climate change.[25]

Other innovative ideas are coming from Latin America, where some cities are establishing watershed trust funds. For instance, Rio de Janeiro in Brazil collects fees from water users to pay upstream farmers and ranchers $71 per hectare ($28 per acre) to protect and restore riparian forests, safeguarding the water supply and preserving habitat for rare birds and primates. A public watershed protection fund in Quito, Ecuador, started in 2000 in partnership with the Nature Conservancy, receives nearly $1 million a year from municipal water utilities and electric companies. Quito's water fund has become a model for other Latin American cities, including Cuenca, Ecuador, and Lima, Peru.[26]

There are many ways communities can work with nature to meet their water needs while reducing energy costs and building resilience. Communities facing increased flood damage, for instance, might achieve cost-effective flood protection by restoring a local river's natural floodplain. After enduring nineteen flood episodes between 1961 and 1997, Napa, California, opted for this approach over the conventional route of channelizing and building levees. In partnership with the Army Corps of Engineers, the $366 million project is reconnecting the Napa River with its historic floodplain, moving homes and businesses out of harm's way, revitalizing wetlands and marshlands, and constructing levees and bypass channels in strategic locations. In addition to increased flood protection and reduced

It could take an additional 1,314 billion cubic meters of water—equal to the annual flow of 73 Colorado Rivers—to meet the world's dietary needs in 2025.

flood-insurance rates, Napa residents will benefit from parks and trails for recreation, higher tourism revenues, and improved habitat for fish and wildlife.[27]

Similarly, communities facing increased damage from heavy stormwater runoff can turn impervious surfaces such as roofs, streets, and parking lots into water catchments by strategically planting vegetation. Portland, Oregon, is investing in "green roofs" and "green streets" to prevent sewer overflows into the Willamette River.[28] Chicago, Illinois, now boasts more than 200 green roofs—including atop City Hall—that collectively cover 2.5 million square feet, more than any other U.S. city. The vegetated roofs are helping to catch stormwater, cool the urban environment, and provide space for urban gardens.[29]

Many communities are revitalizing their rivers by tearing down dams that are no longer safe or serving a justifiable purpose. Over the last decade some 430 dams have been removed from U.S. rivers, opening up habitat for fisheries, restoring healthier water flows, improving water quality, and returning aquatic life to rivers. In the ten years since the Edwards Dam was removed from the Kennebec River near Augusta, Maine, populations of sturgeon, Atlantic salmon, and striped bass have returned in astounding numbers, reviving a recreational fishery that adds $65 million annually to the local economy.[30]

Doing More—and Living Better—with Less Water

Of all the water we withdraw worldwide from rivers, lakes, and aquifers, 70 percent is used in agriculture, 20 percent in industries, and 10 percent in cities and towns. With water supplies tightening, we will need roughly a doubling of water productivity by 2025 to satisfy human needs while sustaining nature's life-support systems. Fortunately, opportunities to get more benefit per drop abound through greater investments in conservation, efficiency, recycling, and reuse, as well as through shifts in what is produced where and when.

But the need to do more with less water is not only a challenge for farmers, utilities, and manufacturers. It is also up to individual consumers to shrink our personal water footprints—the amount of water used to produce all the things we buy. The average U.S. resident uses, directly and indirectly, about 2,480 cubic meters of water per year—about 1,800 gallons *per day*—twice the global average.[31] More conscious choices about what and how much we consume are essential for reducing our global water footprint.

WATER FOR FOOD

Feeding the world is a very water-intensive enterprise. It takes about 3,000 liters of water to meet a person's daily dietary needs. In the United States, with its high consumption of meat (especially grain-fed beef), the average diet requires some 5,000 liters of water per day. Under some very conservative assumptions, it could take an additional 1,314 billion cubic meters of water per year—equal to the annual flow of 73 Colorado Rivers—to meet the world's dietary needs in 2025.[32]

Once again, the search for solutions needs to begin with a reframing of the question. Instead of asking where we can find 73 Colorado Rivers' worth of water, the question is: *How do we provide healthy diets for 8 billion people without going deeper into water debt?* Framed this way, the solutions focus on getting more nutritional value per drop of water used in agriculture, which is the key to solving the water-food dilemma (table 7.1).

There are many ways we can grow more food for the world with less water, with most falling into four broad categories: (1) Irrigate more efficiently; (2) boost yields on existing farms, especially rain-fed lands; (3) choose healthy, less water-intensive diets; and (4) use trade to make the smartest use of local water.

TABLE 7.1
Water Used to Produce Selected Products (global average)

PRODUCT	*WATER USED IN PRODUCTION (LITERS)*
1 tomato	13
1 potato	25
1 slice of bread	40
1 orange / 1 glass of orange juice	50 / 170
1 egg	135
1 cup of coffee	140
1 glass of milk	200
1 hamburger	2,400
1 cotton t-shirt	4,100
1 pair of shoes (bovine leather)	8,000

Source: Adapted from A. K. Chapagain and A. Y. Hoekstra, *Water Footprints of Nations: Vol ume 1: Main Report*, UNESCO Value of Water Research Report Series 16 (Delft: UNESCO-IHE, 2004), 42.

Irrigate more efficiently.

For the last two centuries, societies have focused on expanding irrigation as a key to raising crop production. Today, the 18 percent of cropland that gets irrigation water provides about 40 percent of the world's food—but much of the water withdrawn for farming never benefits a crop. Some of it seeps back into aquifers or nearby streams, while some evaporates back to the atmosphere. There are many ways to reduce the waste: Irrigation can be scheduled to better match crop water needs, for example, or drip irrigation can be used to curb evaporation losses. Reducing irrigation demands by even 10 percent could free up enough water to meet the new urban and industrial demands anticipated for 2025.[33]

Boost yields on rain-fed lands.

Rain-fed croplands have been the neglected stepchild in global agriculture, but this is now changing. Lands watered only by rain produce 60 percent of the world's food. Some, including those in the U.S. Midwest, achieve very high yields. But many rain-fed farms, particularly in poor countries, produce far less than they could. By one estimate, 75 percent of the world's additional food needs could be met by increasing harvests on low-yield farms to 80 percent of what high-yield farms achieve on comparable land. Most of this potential is in rain-fed areas,[34] and it's achievable through small-scale technologies and improved field methods—including, for example, capturing and storing local rainwater to apply to crops via low-cost irrigation systems.[35] Because the majority of the world's poor and hungry live on rain-fed farms in South Asia and sub-Saharan Africa, raising the farms' productivity would directly boost food security and incomes.

Choose less water-intensive diets.

Foods vary greatly both in the amount of water they take to produce and in the amount of nutrition they provide—including energy, protein, vitamins, and minerals. It can take five times more water to supply 10 grams of protein from beef than from rice, for example, and nearly twenty times more water to supply 500 calories from beef than from rice. So eating less meat can lighten our dietary water footprint (while also improving our health). If all U.S. residents reduced their consumption of animal products by half, the nation's total dietary water requirement in 2025 would

It can take nearly twenty times more water to supply 500 calories from beef than from rice.

drop by 261 billion cubic meters per year, a savings equal to the annual flow of 14 Colorado Rivers.[36]

Use trade to make the smartest use of local water. While regional food resilience is important, some water-scarce regions may find it makes better economic and even environmental sense to import more of their food, rather than grow it themselves, and reserve their water for drinking and manufacturing. Egypt, Israel, Jordan, and a dozen other water-scarce countries already import a good share of their grain, saving 1,000–3,000 cubic meters of water for each ton of grain they import. Today, 26 percent of the global grain trade is driven by countries choosing to import water indirectly in the form of grain.[37]

This trade strategy can often be a good alternative to overpumping groundwater or diverting rivers long distances. As water analyst Jing Ma and colleagues point out, northern China annually exports to southern China about 52 billion cubic meters of water indirectly through foodstuffs and other products. This volume exceeds that expected to be shipped from south to north through the massive water-transfer scheme now under construction.[38] A rethinking of where, what, and how food is grown within China might allow the project to be scaled far back, if not eliminated altogether.

At the national level, however, a food policy that relies on grain imports can pose significant risks, especially for poor countries. As China, India, Pakistan, and other populous, water-stressed countries begin to look to the international grain market to meet their rising demands, food prices are bound to increase. The food riots that erupted in Haiti, Senegal, Mauritania, and some half dozen other countries as grain prices climbed in 2007 and 2008 are likely a harbinger of what is to come and suggest that a degree of food self-sufficiency may be crucial to food security.[39] And of course, the rising fuel costs and increased potential for fuel scarcity associated with peak oil will only make food imports more expensive and less reliable in the long run.

WATER FOR HOMES AND MANUFACTURING

Changes in the production and consumption of manufactured goods can also shrink our water footprints. For example, Unilever is taking steps to reduce water use across the life cycle of its products, from raw materials to manufacturing to packaging to consumer use. Since 1995, water use in its factories has dropped 63 percent, with some of its factories now treating and reusing all of their process water. Unilever is also working with its raw material suppliers to help conserve water. For example, by installing drip irrigation systems on a Tanzanian tea plantation and on a Brazilian tomato farm, the company is shrinking the water footprint of its Lipton tea and Ragu tomato sauce.[40]

In communities across the United States, conservation remains the least expensive and most environmentally sound way of balancing water budgets—and its potential has barely been tapped. Many cities and towns have shown significant reductions in water use through relatively simple measures like repairing leaks in distribution systems, retrofitting homes and businesses with water-efficient fixtures and appliances, and promoting more sensible and efficient outdoor water use. For example, a highly successful conservation program started in Boston in 1987 cut total water demand 43 percent by 2009, bringing water use to a fifty-year low and eliminating the need for a costly diversion project from the Connecticut River.[41]

The greatest residential water-conservation gains yet to be made lie in smarter landscape choices and watering practices. Turf grass covers some 16.4 million hectares (40.5 million acres) in the United States—an area three times larger than any irrigated farm crop in the country. Particularly in the western United States, where outdoor watering typically accounts for 40 to 70 percent of household water use, converting thirsty green lawns into native drought-tolerant landscaping can save a great deal of water. Las Vegas now pays residents $2 for each square foot of grass they rip out, which has helped shrink the city's turf area by 80 million square feet and lower its annual water use by 18 billion gallons in just four years.[42] Albuquerque, New Mexico, has reduced its total water use by 21 percent since 1995 largely through education and by providing rebates to residents for using water-conserving irrigation systems.[43]

One of the biggest untapped potentials for smarter water management in all types of enterprises lies in more creative use of information technologies: meters, sensors, controllers, computers, and even cell phones. A little book-sized product called iStaq, made by U.K.-based Qonnectis, fits under a manhole cover and measures flow, pressure, and other water variables. If the water pipe springs a leak, the iStaq alerts the utility operator by text message. In farming regions, real-time weather data collection combined with crop evapotranspiration rates and sensors monitoring soil moisture are helping farmers determine when and how much to irrigate their crops. There's even an iPhone application that enables farmers to remotely monitor moisture levels in their fields through sensors placed near the roots of their crops.

Drip irrigation feeds water directly to crops.

In Ugandan villages, farmers lacking computers are getting access to the wealth of information on the Internet by calling their questions in to a free telephone hotline called Question Box. The operators, who speak the local language, search for the answers and call the farmers back. A project of Open Mind, a California-based nonprofit, Question Box enables poor farmers, whose only communication device may be a village phone, to connect to the wired world for information on crop prices, weather forecasts, plant diseases, and more.[44]

The potential uses of information technology to enable smarter water decisions are extensive and have only begun to be tapped. Using GIS (geographic information system) technology, for example, the World Wildlife Fund (WWF) recently identified more than 6,000 traditional water tanks (small reservoirs to capture rainfall or runoff) in a single sub-watershed in western India. WWF determined that if the tanks were restored to capture just 15 to 20 percent of local rainfall, they could

> Most of the world's water shortages have arisen because the policies and rules that motivate decisions about water have encouraged inefficiency and misallocation.

hold some 1.74 billion cubic meters of water—enough to expand irrigated area in the region by 50 percent and at a cost per hectare just one-fourth that of an irrigation dam-and-diversion project proposed for the region.[45]

Resetting the Signals

Most of the world's water shortages have arisen because the policies and rules that motivate decisions about water have encouraged inefficiency and misallocation rather than conservation and wise use. Without big dams and river diversions subsidized by taxpayers, for example, rivers and streams in the western United States would not be so severely depleted today. And without low, flat rates for electricity, India's groundwater would not be so severely overpumped.

Allowing markets to do what they can do well—send a price signal about water's value—is critical for encouraging investments in water efficiency and more sensible uses of water. Most governments in rich and poor countries alike, however, continue to send the wrong signal by heavily subsidizing water, especially for irrigation, the biggest consumer. While better pricing is essential, it doesn't automatically account for the many important benefits of rivers, lakes, wetlands, and streams—such as protecting water quality and providing fish and wildlife habitat—that are not recognized in the marketplace. It is the job of governments, as custodians of the public trust in water, to protect these important but often unrecognized values, and it is the job of citizens to demand that their elected officials get busy crafting creative solutions.

Imagine, for example, if U.S. policy-makers propped up farm incomes not with irrigation and crop subsidies that distort markets and misallocate resources, but rather with payments for protecting ecosystem services that benefit society at large. Farmers and ranchers who plant buffer strips along streams, protect soils from erosion, or provide wildlife habitat through wetland protection would receive a payment for providing these services. The Conservation Reserve Program under the U.S. Department of Agriculture (USDA) could be strengthened to secure these water benefits for the long term, perhaps in conjunction with the USDA's new Office for Ecosystem Services and Markets. A tax on water depletion or transfers could help fund the effort.[46]

Current pricing and policy signals are deeply misaligned with the realities of our water predicament—but this means that there are untold opportunities for improvement. Each of the ideas listed in box 7.1 has been implemented by some local, state, or national government somewhere, and has achieved positive results. For example, a cap on groundwater pumping from the Edwards Aquifer in south-central Texas has motivated farmers, businesses, and citizens to conserve. San Antonio has cut its per capita water use by more than 40 percent to one of the lowest levels of any western U.S. city.[47]

It is critical that policy-makers begin to grapple with the inconvenient truth that supplying water takes energy and supplying energy takes water. Energy and water are tightly entwined, and all too often public policies to "solve" one problem simply make the other one worse. For example, the 2007 mandate of the U.S. Congress[48] to produce 15 billion gallons of corn ethanol a year by 2015 would annually require an estimated 6 trillion liters of additional irrigation water (and even more direct rainfall)—a volume exceeding the annual water withdrawals of the entire state of Iowa.[49] Even solar power creates a demand for water, especially some of the big solar-thermal power plants slated for the sunny Southwest.[50] Clearly any action we take to build local renewable energy sources must be careful not to add additional strain to our already-stressed rivers and aquifers.

The win-win of the water-energy nexus, of course, is that saving water saves energy, and saving energy saves water. The more a community lives on water, energy, and food produced locally, the more options arise for solving multiple problems simultaneously, building resilience through resourcefulness, and preparing for future uncertainties.

BOX 7.1

Ideas to Transition to a More Secure Water Future

- Cap groundwater and river depletion.
- Reduce subsidies; price water to better reflect its value.
- Protect wetlands and watersheds to safeguard water quality.
- Re-operate (improve the release of water) or remove dams so as to restore natural river flows.
- Establish payments for ecosystem services.
- Offer rebates or tax credits for conservation and efficiency measures.
- Encourage "green infrastructure" (e.g., roofs, streets) in urban and suburban areas.
- Reduce individual/corporate/community water footprints.
- Ensure that decision-making is inclusive, transparent, and accountable to the public.

Endnotes

1 Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007—The Physical Science Basis*, (Cambridge, UK: Cambridge University Press, 2007); and IPCC, "Summaries for Policymakers," in *Climate Change 2007—Impacts, Adaptation and Vulnerability*, (Cambridge, UK: Cambridge University Press, 2007).

2 Tim Pearce, ed., "Natural Disasters Displacing Millions—U.N. Study," *Reuters*, September 22, 2009; Robert Draper, "Australia's Dry Run," *National Geographic*, April 2009, 35-59; Heather Timmons, "Half a Million Are Stranded by India Flood," *The New York Times*, September 1, 2008; Mian Ridge, "India's Farmers Struggle Without Crucial Monsoon Rains," *Christian Science Monitor*, August 25, 2009; Paul Rodgers, "Millions Facing Famine in Ethiopia as Rains Fail," *The Independent*, August 30, 2009.

3 "Iowa Flood, Midwest Flooding: Videos, Maps, News and Background," Geology.com, June 13, 2008, http://geology.com/events/iowa-flooding/; "Governor Sonny Perdue Prays for Rain in Georgia, WDEF.com, November 14, 2007; Robbie Brown and Liz Robbins, "Rain Stops, but 8 are Dead in Southeast Floods," *The New York Times*, September 22, 2009.

4 P.C.D. Milly et al., "Stationarity is Dead: Whither Water Management?" *Science* 319 (February 1, 2008), 573-574.

5 Ibid., for $500 billion annual global investment figure.

6 Stuart Bunn, presentation at the 94th Annual Meeting of the Ecological Society of America, Albuquerque, NM, August 2-7, 2009; for an excellent narrative on the Australian drought, see Robert Draper, "Australia's Dry Run," *National Geographic*, April 2009, 35-59.

7 Tim Barnett and David Pierce, "When Will Lake Mead Go Dry?" *Water Resources Research* 44 (March 29, 2008).

8 Richard Seager et al., "Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America," *Science* 316 (May 25, 2007), 1181-1184.

9 Population figures from Population Reference Bureau (PRB), *2009 World Population Data Sheet*, http://www.prb.org/.

10 Just six countries (Brazil, Russia, Canada, Indonesia, China, and Colombia) account for half the water annually flowing back toward the sea in rivers, streams and underground aquifers—what hydrologists call "runoff," according to the United Nations Food and Agriculture Organization (FAO), *Review of World Water Resources by Country*, (Rome: FAO, 2003).

11 Number of large dams (those at least 15 meters high) from World Commission On Dams, *Dams and Development* (London: Earthscan Publications, 2000); Jamie Pittock et al., "Interbasin Water Transfers and Water Scarcity in a Changing World—A Solution or a Pipedream?" (Frankfurt: World Wildlife Fund Germany, August 2009).

12 Sandra Postel, "Where Have All the Rivers Gone?" *World Watch 8* (May/June 1995); Fred Pearce, *When the Rivers Run Dry* (Boston: Beacon Press, 2006).

13 Sandra Postel, *Pillar of Sand: Can the Irrigation Miracle Last?* (New York: W.W Norton & Co., 1999).

14 Matthew Rodell, Isabella Velicogna, and James S. Famiglietti, "Satellite-based Estimates of Groundwater Depletion In India," *Nature* 460 (August 20, 2009).

15 V.L. McGuire, *Ground Water Depletion in the High Plains Aquifer, Predevelopment to 2005*, U.S. Geological Survey Fact Sheet 2007-3029, 2007, http://pubs.er.usgs.gov/; 30 percent figure from U.S.G.S., "High Plains Regional Ground Water (HPGW) Study," http://co.water.usgs.gov/nawqa/hpgw/HPGW_home.html.

16 Jamie Pittock et al., "Interbasin Water Transfers and Water Scarcity in a Changing World"; total transfer volume from Ruixiang Zhu, "China's South-North Water Transfer Project and Its Impacts on Economic and Social Development," People's Republic of China Ministry of Water Resources (2008).

17 Kenneth Pomeranz, "The Great Himalayan Watershed: Agrarian Crisis, Mega-Dams and the Environment," *New Left Review* 58, (July-August 2009); estimates of India's irrigated area vary widely depending on the source and estimation method per Prasad S. Thenkabail, et al., "Irrigated Area Maps and Statistics of India Using Remote Sensing and National Statistics," *Remote Sensing* 1, no.2 (April 17, 2009), 50-67.

18 Brian D. Richter, "Lost in Development's Shadow: The Downstream Human Consequences of Dams," World Commission on Dams, forthcoming.

19 Robert Wilkinson, *Methodology for Analysis of the Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures*, Environmental Studies Program, University of California, Santa Barbara (2000), 6; QEI, Inc., *Electricity Efficiency Through Water Efficiency, Repo rt for the Southern California Edison Company*, (Springfield, NJ: 1992), 23-24.

20 Debbie Cook, former Mayor of Huntington Beach (Calif.), has said "The next worst idea to turning tar sands into synthetic crude is turning ocean water into municipal drinking water.", quoted in "Desalination—Energy Down the Drain," The Oil Drum, March 2, 2009, http://www.theoildrum.com/node/5155.

21 Quirin Schiermeier, "Purification with a Pinch of Salt," *Nature* 452, no.7 (March 20, 2008), 260-261.

22 National Academy of Sciences, Water Science and Technology Board, *Desalination: A National Perspective*, (Washington DC: National Academy Press, 2008); 15,000 figure from Schiermeier, "Purification with a Pinch of Salt."

23 NAS Water Science and Technology Board, *Desalination: A National Perspective*.

24 Sandra Postel, *Liquid Assets: The Critical Need to Safeguard Freshwater Ecosystems*, Worldwatch Paper 170, (Washington, DC: Worldwatch Institute, 2005).

25 Sandra Postel and Barton H. Thompson, Jr., "Watershed Protection: Capturing the Benefits of Nature's Water Supply Services," *Natural Resources Forum* 29, no.2 (May 2005), 98-108.

26 Cara Goodman, "South America: Creating Water Funds for People and Nature," The Nature Conservancy, http://www.nature.org/. For more examples and a fuller description of Quito's fund, see Postel, *Liquid Assets*.

27 National Research Council, *Valuing Ecosystem Services: Toward Better Environmental Decision-Making* (Washington, D.C.: The National Academy Press, 2005); $366 million figure from David G. Killam, "Sacramento District Project Wins Public Works Project of the Year," website of the U.S. Army, February 12, 2009, http://www.army.mil/.

28 Will Hewes and Kristen Pitts, *Natural Security: How Sustainable Water Strategies are Preparing Communities for a Changing Climate* (Washington, DC: American Rivers, 2009).

29 Emily Pilloton, "Chicago Green Roof Program," Inhabitat, August 1, 2006, http://www.inhabitat.com/2006/08/01/chicago-green-roof-program/.

30 Number of 430 dams is from Rebecca Wodder, "Tolling Bells Ushered in Kennebec River's Rebirth," *Kennebec Journal & Morning Sentinel*, June 28, 2009; $65 million figure is from Hewes and Pitts, *Natural Security*; for more on dams and rivers, see Sandra Postel and Brian Richter, *Rivers for Life: Managing Water for People and Nature*, (Washington, DC: Island Press, 2003).

31 A. Y. Hoekstra and A. K. Chapagain, "Water Footprints of Nations: Water Use by People as a Function of their Consumption Pattern," *Water Resources Management* 21, no.1 (2006), 35-48.

32 For this calculation, I assumed that the 1.2 billion people who will join humanity's ranks over the next fifteen years will eat low-meat diets, and I made no allowance for the 850 million people who don't have enough food today, nor for the increasing dietary water requirements in China and elsewhere as incomes rise; hence it is very conservative.

33 Postel, *Pillar of Sand*; 2025 calculation based on withdrawal estimates in William J. Cosgrove and Frank R. Rijsberman, *World Water Vision: Making Water Everybody's Business* (London: Earthscan, 2000).

34 David Molden, ed., *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture* (London: Earthscan, and Colombo: International Water Management Institute, 2007).

35 For a fuller description, see Postel, *Pillar of Sand*, chapter 9; useful websites include those of the International Water Management Institute, at www.iwmi.cgiar.org, which also has many informative publications; for more on rainwater harvesting, see the website of the Centre for Science and Environment in Delhi, India, at www.cseindia.org, especially their site, www.rainwaterharvesting.org; for examples of affordable, small-plot irrigation, see especially International Development Enterprises, at www.ideorg.org.

36 Dietary water requirement from D. Renault and W.W. Wallender, "Nutritional Water Productivity and Diets," *Agricultural Water Management* 45 (2000), 275-296; calculation assumes average annual dietary water requirement drops from 1,971 cubic meters per person to 1,242; U.S. 2025 population of 358.7 million is the medium variant estimate of the Population Division of the Department of Economic and Social Affairs of the United Nations, *World Population Prospects: The 2008 Revision*, http://esa.un.org/unpp.

37 Analysis of grain import dependence based on data from U.S. Department of Agriculture, Foreign Agricultural Service, "Production, Supply and Distribution Online," at http://www.fas.usda.gov/psdonline.

38 Jing Ma et al., "Virtual Versus Real Water Transfers Within China," *Philosophical Transactions of the Royal Society B* 361 (2006) 835-842.

39 Postel, *Pillar of Sand*; Sandra Postel, "But Who Will Export Tomorrow's Virtual Water," in *The Truth About Water Wars*, SEED, May 14, 2009, http://seedmagazine.com/.

40 Sandra Postel and Amy Vickers, “Boosting Water Productivity,” *State of the World 2004* (Washington, DC: Worldwatch Institute, 2004), 46-65; Unilever example from *Sustainable Development Report 2007: Environmental Sustainability*, (Unilever, 2007).

41 For conservation methods and examples, see Amy Vickers, *Handbook of Water Use and Conservation: Homes, Landscapes, Businesses, Industries, Farms* (Amherst, MA: WaterPlow Press, 2001); Boston example from Sandra Postel, *Liquid Assets*, and Sandra Postel, “Lessons from the Field—Boston Conservation,” National Geographic website, March, 2010, http://environment.nationalgeographic.com/environment/freshwater/lessons-boston-conservation/.

42 Cristina Milesi et al., “Mapping and Modeling the Biogeochemical Cycling of Turf Grasses in the United States,” *Environmental Management* 36 (September, 2005), 426-438; Dara Colwell, “Our Love Affair With Our Lawns is Hurling the U.S. Toward Water Crisis,” AlterNet, October 2, 2009, http://www.alternet.org/; Las Vegas figures from Robert Glennon, *Unquenchable: America’s Water Crisis and What To Do About It* (Washington, DC: Island Press, 2009).

43 Personal email communication with Katherine M. Yuhas, Water Conservation Officer, Albuquerque Bernalillo County Water Authority, Albuquerque, NM, October 12-13, 2009. Between 1995 and 2008, Albuquerque’s total water production declined from 40.775 billion gallons to 32.247 billion gallons, while the population served increased from 445,167 to 559,828.

44 iStaq example from Matthew Power, “Peak Water: Aquifers and Rivers are Running Dry. How Three Regions are Coping,” *Wired Magazine* 16, no. 5 (April 21, 2008); “iPhone App Offers Remote Water Sensing For Farmers, *The New York Times*, June 30, 2009; see the website for Question Box at http://questionbox.org, and Ron Nixon, “Dialing for Answers Where Web Can’t Reach,” *The New York Times*, September 28, 2009.

45 Jamie Pittock et al., “Interbasin Water Transfers and Water Scarcity in a Changing World.”

46 For more examples, see Sandra Postel and Barton H. Thompson Jr., “Watershed Protection: Capturing the Benefits of Nature’s Water Supply Services,” *Natural Resources Forum* 29 (May 2005), 98-108.

47 Edwards Aquifer Authority website, at www.edwardsaquifer.org; water use from San Antonio Water System, *2008 Annual Report*.

48 U.S. Congress, Energy *Independence and Security Act of 2007*, 110th Cong., 1st session, 2007.

49 R. Dominguez-Faus et al., “The Water Footprint of Biofuels: A Drink or Drive Issue?” *Environmental Science & Technology* 43 (May 1, 2009), 3005-3010.

50 Todd Woody, “Alternative Energy Projects Stumble on a Need for Water,” *The New York Times*, September 30, 2009.

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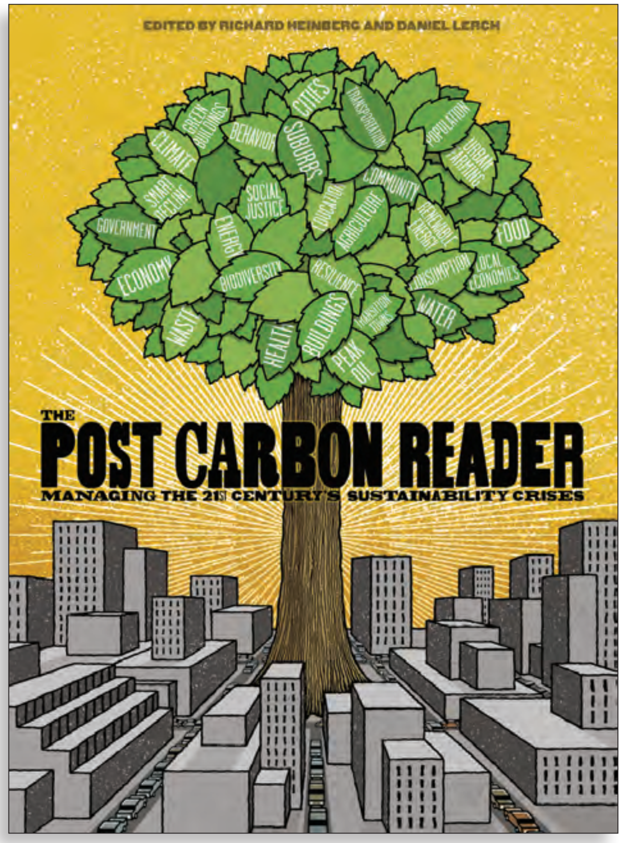

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