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It takes **2500 gallons** of water to grow a pound of coffee,

3000 gallons of water to

make a quarter pounder,

and **600 gallons** of water to make a pound of cheese

No wonder the Earth is running dry...

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Our demand for water has turned us into vampires, draining the world of its lifeblood. What can we

JAYANTA SHAW/REUTERS

BY CONVENTIONAL measures, Jitbhai Chowdhury is a model farmer. He uses organic manure and natural pesticides. He grows fruit trees round the edge of his alfalfa fields and tends his dairy cattle with care. Every day he produces 25 litres of milk which he sends to a collection point in the nearby village of Kushkal in Gujarat, India, for delivery to the state dairy. It's because of people like him that India isn't starving.

But for all its virtues, Chowdhury's 2-hectare farm is sowing the seeds of a global disaster. To grow the fodder that he needs to feed his cows, he is entirely dependent on irrigation water pumped from deep underground. Over the course of a year, his small electric pump sucks twice as much water from beneath his fields as falls on the land as rain. No wonder the water table in the village is 150 metres down and falling by 6 metres a year.

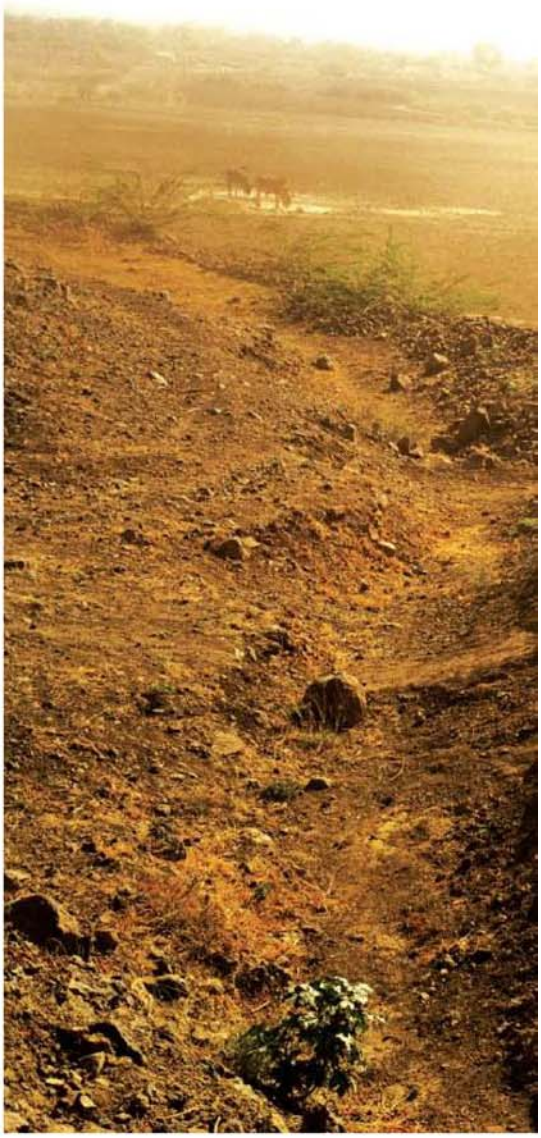
Chowdhury is one of millions of farmers doing this across the world. From China to Argentina, and Australia to the US, people are increasingly dependent on "fossil" water extracted unsustainably from deep underground. Collectively, our actions are threatening to revive a spectre that nobody has seriously worried about for the best part of 40 years – mass global starvation.

Back in the 1960s, the world was gripped by a Malthusian nightmare. The planet's population was set to double in a generation, and nobody knew how everyone would be fed. Scare stories abounded. In 1968, for example, Stanford University biologist Paul Ehrlich wrote in his best-selling book *The Population Bomb* that "the battle to feed all of humanity is over...hundreds of millions of people are going to starve to death."

The apocalypse didn't happen, thanks largely to a new generation of high-yielding varieties of crops such as rice, wheat and maize. What is less well known is that the success of this "green revolution" was built on a massive investment in irrigation systems. Today the world grows twice as much food as it did a generation ago, but it uses three times as much water to grow it. Two-thirds of all the water abstracted from the environment goes to irrigate crops. This use of water is massively unsustainable, and has led many people to conclude that the apocalypse wasn't averted, only postponed.

In most places, irrigating crops means building dams and emptying rivers into irrigation canals. This is not good for rivers and their ecosystems, though at least the rivers refill when it rains. However, in some places rivers do not have enough water in them to sustain the demands being made on them. So farmers have taken matters into their own hands.

The starkest example is India. Over the past decade, the country has seen an extraordinary "barefoot" hydrological revolution. Farmers have hired drilling rigs and bought electric pumps to mine water that has sat undisturbed beneath their fields for millennia. Today, more than 21 million Indian farmers tap ▶



Rivers are running dry all over the world, not just here in the village of Bankura, India

The parched planet

do to prevent mass global drought and starvation, asks **Fred Pearce**

JOHAN ROUSSEL/OTTONEL PUBLIC

underground reserves to water their fields, and two-thirds of India's crops are irrigated with underground water. This water is running out. Unlike the rivers, it will not be quickly replaced. And where India leads, the rest of the world looks set to follow.

There are no reliable statistics on how much water India's farmers pump from beneath the ground. The International Water Management Institute (IWMI), part of a worldwide network of agricultural research centres funded by the World Bank, recently estimated that about 250 cubic kilometres of water are abstracted for irrigation each year. That is at least 100 cubic kilometres more than the rains put back. It feeds India. But as every year passes, the aquifers get emptier.

"It's a colossal anarchy, a one-way trip to disaster," says Tushaar Shah of the IWMI. Shah has spent more than a decade following India's groundwater revolution from his research station in Anand in the arid Indian state of Gujarat. He says Indian farmers are draining their water reserves with reckless abandon, growing thirsty crops such as rice, sugar cane, alfalfa and cotton. The farmers are certainly destroying their children's future, if not their own.

Fossil water from deep underground is only a temporary fix for the millions that depend on it

The government has no idea what to do. "Regulation is virtually impossible," says Shah. "Nobody knows where the pumps are, or who owns them. There is no way anyone can control what happens to them."

"This has all just exploded in the past decade, since the arrival in India of cheap pumps. The juggernaut is still accelerating. There are a million more pumps every year. We are only just beginning to see the consequences." Shah estimates that at least a quarter of Indian farmers are mining underground water that nature will not replace, and that up to 200 million people face a waterless, foodless future.

The groundwater boom is turning to bust and, for some, the green revolution is over. Fifty years ago in northern Gujarat, bullocks driving leather buckets lifted water from open wells dug to about 10 metres. Now tube wells are sunk to 400 metres, and they still run dry. Half the traditional hand-dug wells and millions of tube wells have dried up across western India. In the southern state of Tamil Nadu, two-thirds of the hand-dug wells have failed already, and only half as much land is irrigated as a decade ago. Whole districts in Tamil Nadu and Gujarat are emptying of people. Suicides among farmers are rife. Many more are joining the millions migrating to urban slums or joining the gangs of construction workers and labourers travelling the roads of India.

The real cost of milk

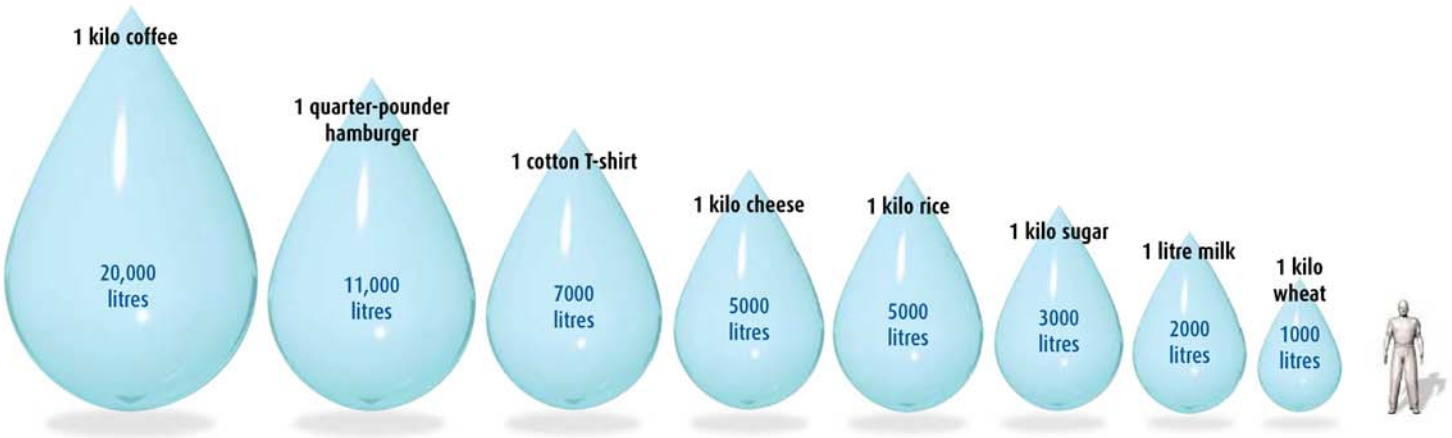
As the water tables fall, some states find that most of their heavily subsidised electricity is being used by farmers to pump water to the surface. Legislators see no way of stopping the practice. "If the electricity sold to farmers for pumping were charged at its full market price, nothing would grow except what the rains can sustain," Shah says. Sometimes the grids cannot take the strain and there are widespread blackouts – this is the only effective limit on pumping.

It is not a case of bad people doing bad things. Far from it, as I discovered when I visited Chowdhury on his dairy farm.

AMIT DAVE/REUTERS

THIRSTY WORK

It takes staggering quantities of water to grow some common crops – water that many countries cannot afford to lose



Shah's researchers reckon he is the most efficient and ecologically minded farmer in the area. However, probe a little deeper and Chowdhury's very efficiency illustrates the madness of the water economics being played out here. His electric pump brings up 12 cubic metres of water an hour. When he needs to irrigate his fields, which he does 24 times a year, it takes 64 hours to pump up all the water he needs. That adds up to 18,000 cubic metres of water a year to grow the fodder to produce just over 9000 litres of milk. That's 2000 litres of water for every litre of milk. According to Shah that is better than the local average.

Some have called the dairy industry here a "white revolution". But, says Shah, it is one of the major reasons for the water crisis in Gujarat. He thinks two districts alone are, in effect, exporting from the state 1.5 cubic kilometres of water a year in the form of milk.

Chowdhury understands all too well the bind that he and his fellow water plunderers are in. "Yes, I'm worried that the water will disappear," he tells me. "But what can I do? I have to live, and if I don't pump it up, my neighbours will." Everyone has unrestricted access, so over-exploitation is almost inevitable; it's a classic case of the tragedy of the commons. As we gave him a lift into the village to deliver his milk, he added: "I don't want my son to do farming. I want him to get a job in the city." At the rate the water table is dropping, he may not have any choice.

The Indian underground water anarchy is already being repeated elsewhere. From China to Iran and Indonesia to Pakistan, rivers are running dry under the impact of increased abstractions and, in some places, climate change. Millions of small farmers have bought pumps and are sucking water from beneath their fields. Shah estimates that India, China and Pakistan together probably pump out around 400 cubic kilometres of underground water a year, around twice as much as is recharged by the rains. These three countries account for more than half the world's total use of underground water for agriculture.

Meanwhile, in the past decade Vietnamese farmers have quadrupled the number of tube wells to more than a million. Sri Lanka, Indonesia, Iran and Bangladesh are not far behind. Outside Asia similar revolutions are under way in heavily populated countries such as Mexico, Argentina, Brazil and Morocco. Even the US is busy emptying precious groundwater reserves in order to grow grain and beef for export.

These countries are at the heart of what agronomist and environmentalist Lester Brown, president of the Earth Policy Institute in Washington DC, calls a "food bubble". Record farm outputs in recent years, he says, have been made possible only by an unsustainable assault on this fast-diminishing resource. The bubble is bound to burst. "The question is not if, but when," he says. The consequences of the eventual, inevitable failure of underground water could be catastrophic. It is a slow-burning drought disaster that will one day affect hundreds of millions of people. Yet so far it has not registered on the radar screens of governments or aid agencies.

It won't happen everywhere at the same time, of course. Each aquifer has its own countdown to destruction. As each bubble bursts, it will undermine the world's ability to feed itself. Nor is this just a crisis for the developing world. By some calculations, as much as a tenth of the world's food is being ▶

Irrigating crops with water that cannot be replenished by rain contributes to a worldwide "food bubble"

GRAHAM MARSHALL SMITH/CORBIS

JAYANTA SHAW/REUTERS

When a river runs dry, is there any choice but to buy an electric pump to start on the groundwater?

grown using underground water that is not being replaced by the rains. Without our knowing it, much of the rich world is importing crops grown using over-pumped underground water reserves – cotton from Pakistan, rice from Thailand, tomatoes from Israel, coffee from Ethiopia and even Spanish oranges and Australian sugar.

Many of us, particularly in countries where farming does not rely on artificial irrigation, have little idea how much water it takes to grow our food. Some of the statistics are staggering. It takes between 2000 and 5000 litres of water to grow 1 kilogram of rice, for instance. That is more water than many households use in a week. For just a bag of rice. It takes a thousand litres to grow a kilo of wheat, 11,000 litres to grow the feed for enough cow to make a quarter-pound hamburger and between 2000 and 4000 litres for that cow to fill its udders with a litre of milk.

If you think your shopping basket is getting a trifle bulky at this point, maybe you should leave that kilogram bag of sugar on the shelf. It took up to 3000 litres of water to produce. And the kilo jar of coffee tips the scales at 20,000 litres – 20 tonnes – of water. Looked at another way, every teaspoonful of sugar in your coffee requires 50 cups of water to grow it. Growing the coffee itself requires 140 litres of water, or 1120 cups. In ways such as this, a typical meat-eating, milk-guzzling westerner consumes as much as a hundred times their own weight in water every day. Clothing only adds to the hydrological pain. You could fill 25 bathtubs with the water that grows the 250 grams of cotton needed to make a single T-shirt.

Economists refer to the water tied up in the growing and manufacture of products traded internationally as "virtual water". The trade is estimated at around a thousand cubic kilometres a year, or 20 river Niles. Approaching one-tenth of all the water used in raising crops goes into the international virtual water trade. "It moves water in volumes and over distances beyond the wildest imaginings of water engineers," says Tony Allan of the School of Oriental and African Studies in London, who coined the term virtual water. It is emptying the world's underground water reserves.

What is to be done? The Indian government, like some others, has talked a lot recently about providing more water for farmers by linking existing rivers to create a kind of national water grid (*New Scientist*, 7 June 2003, p 30). However, the practical benefit seems uncertain when most of India's rivers are already running dry, and the cost of such a scheme – estimated to be as much as $200 billion – seems daunting. There is another approach. One peculiarity of India's water is that a great deal of it neither reaches rivers nor collects underground. The monsoon rains often evaporate in the sun or run away in flash floods. So one solution being widely discussed is to catch the rain.

In the backwoods of Gujarat, I met Haradevsinh Hadeja, a retired Indian police officer who has transformed his home village of Rajsamadhiya by doing just that. He has turned a near-desert landscape of desiccated fields and empty wells into a verdant scene of trees, ponds, full wells and abundant crops. Most of the other villages in the area rely on government water tankers to provide drinking water for much of the year. They have little left to irrigate their crops. That's not the case in Rajsamadhiya. "We haven't had a water tanker come to the village for more than 10 years. We don't need them," Hadeja says.

Rain harvest

Hadeja has redesigned the village's drainage system to slow the passage of the monsoon rain long enough for it to collect in specially dug ponds. The water passes from one pond to the next in a slow cascade. The villagers don't use the water directly from the ponds, but allow it to percolate into the soil to refill underground reserves and replenish their wells. "There is no more rain than before. We just use it better. We don't let it wash away," Hadeja says. As a result, the village has twice as much water as before; and wells find water at only 7 metres down, where once the water had to be hauled up more than 30 metres.

News about this remarkable village has spread round India and beyond. One foreign scientist arrived in Rajsamadhiya with satellite images of the village that showed up hidden cracks in the geology through which water flowed. Hadeja slowed the flow by plugging the cracks with concrete. Behind the concrete and the satellite images, Hadeja has unknowingly tapped into an old tradition. Until the early 19th century, much of India was irrigated from shallow mud-walled reservoirs in valley bottoms that captured the monsoon rains each summer. The Indians called them tanka, a word adopted into English as tanks.

You can still see old ponds and lakes dotted through the countryside and on wasteland in cities. Most are abandoned. But now, as rivers fail and underground reserves dry up, there are efforts to revive them. "Rainwater harvesting" is becoming a social movement, uniting many strands of Indian society. I met Gandhian social reformers and Hindu swamis, teachers and architects all putting theory into practice. "Even cities can do it," says Sunita Narain, director of the New Delhi-based Centre for Science and Environment and an outspoken advocate. In Bangalore, India's "Silicon Valley", the city authorities are trying to boost the aquifers by rehabilitating the city's 60 ancient lakes. "In parts of Delhi where old tanks and ponds have been cleared of garbage and refilled with water, the water tables are rising," says Narain. If it got organised, the capital could obtain a third of its water from harvesting the rains, she says.

Rainwater harvesting has been pioneered in India, yet it may offer solutions much more widely. In countries as far apart as Mexico, Peru, China and Tanzania, governments and communities are experimenting with similar schemes that avoid the need for large infrastructure, give control over water back to villages, and restore some ecological balance, because they can only tap the rainwater that actually falls.

Shah says that in India at least, a major factor is communal control. Few individual farmers can successfully catch their own rain and store it underground – it would quickly dissipate into the wider aquifer. But when an entire village does it, the effects are often spectacular. Water tables rise, dried-up streams flow again and, with more water for irrigation, the productivity of fields is transformed.

The rainwater harvesting movement, Shah says, is "mobilising social energy on a scale and intensity that may make it one of the most effective responses to an environmental challenge anywhere in the world". Its emergence has been completely autonomous from government – rather like the groundwater revolution, in fact. By some estimates, 20,000 villages in India are now harvesting their rains. Of course there is no more water than before, but local harvesting does seem to be a key to using it more efficiently and sustainably. It might just rescue the world from hydrological anarchy. ●

Fred Pearce's new book *When the rivers run dry* is published in the UK this week (Eden Project Books), and on 25 March in the US (Beacon Press)