THE CURT BERGFORS FOOD PLANET PRIZE

SPECIAL REPORT BY **DAN SALADINO**
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Freshwater: precious and under threat

For too long, we assumed water was an unlimited resource. We were wrong. In our bid to feed a growing population, we have tripled the amount of water used in agriculture, emptying rivers and underground reservoirs and devastating wetlands. Food production now accounts for 70% of all water used by humans. But agriculture is increasingly a victim of water scarcity not just a cause of it. The vast amount of water we are taking from nature is a loan that cannot be repaid, making global food supplies vulnerable. By 2050, half of us may experience water shortages due to increased demand, polluted supplies and climate change. If we're to avoid a catastrophic water crisis, we need to transform the way we farm and eat.

PHOTO: GETTY IMAGES

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PHOTO: ARTUR MELEZ TIXILISKI

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Future water crisis? It's already happening

The remainder of the 21st century is likely to be defined by water: its abundance in some parts of the world and its shortage in others. Wherever you look in the world you can find examples of the impact of a growing global water crisis. And wherever water shortages occur, food production is usually both the cause and the casualty.

"Aquifers are the aquatic equivalent of bank accounts. Finite in capacity, they cannot be endlessly withdrawn from, and replenishing them – which is not always possible – can take years"

Nearly 1.8 billion people in seventeen countries – a quarter of the world's population – are careering towards what the World Resources Institute deems "severe" water shortages in the next few years. Forty-four more countries – home to another third of the planet's people – face "high" levels of water stress. Among the countries most at risk is Jordan (with neighbouring countries in the Middle East making up the majority of the ten most severely water-stressed nations in the world). A hot, dry climate and lack of rainfall aren't the only factors at play in the region; a growing population, rising demand from agriculture and changing diets are also helping to push these countries into a precarious water situation.[i]

The Azraq oasis in Jordan's eastern desert provides a powerful example of the kind of disaster that increased resource pressure can bring. For generations, the oasis, a natural wetland area 120 km northeast of Amman, provided water to traditional communities such as the Druze. Each year, when the winter rains

Circles of crops in Wadi Rum, Jordan, are irrigated using water drawn from an aquifer.
PHOTO: GETTY IMAGES

came, the water table would rise and flood a vast landscape of mudflats. In these spring-fed marshes around the oasis, the Druze grazed small herds of cattle and sheep on lush pasture and grew date palms; and in the waist-high, deep-water pools that formed around the oasis, they caught fish. All of this – the mudflats, the marshes and pools, and the Druze way of life – depended on the hidden reserves of water deep underground that were replenished by the annual rains.

"As Jordan's aquifers run dry, the knock-on effects become more apparent, and range from soil degradation to widespread erosion and the loss of biodiversity and wildlife"

Despite the country's challenging climate (searing temperatures and arid soils in the summer; frost and wind in the winter), the Jordanian government embarked in the 1980s on a plan to grow more food in the desert, planting vast tracts of vegetables, fruit trees, grapevines, and olive trees, as well as cereals intended for livestock feed. To irrigate the new farms, engineers began drilling wells around Azraq and pumping millions of cubic metres of water from aquifers, those underground layers of porous rock that store ancient reserves of water. In the belief that the supply of underground water was endless, individual farmers also began pumping water out of hundreds of wells they drilled themselves. But aquifers are the water equivalent of bank accounts; they have a finite capacity and cannot be endlessly withdrawn from, especially since it can take years for rains to replenish them. The huge increase in demand from irrigation meant that by the late 1980s, the springs that fed the main pools in and around Azraq stopped flowing. By 1990, the pools had dried up all together. The water table that was once close to the surface dropped tens of metres below ground. It's now a question of when, not if, the aquifers will become fully depleted.[ii]

This catastrophe is not confined to Azraq. Nearly two-thirds of Jordan's water supply comes from aquifers, and across the nation, these are drying up.[iii] Some reservoirs are non-renewable; rains cannot replenish them, so once the water is extracted, it's gone forever. With few other freshwater options, Jordan is struggling to navigate the impacts of warmer temperatures and declining water supplies whilst its population, and its demand for food, grows. (It is also sheltering more than a million Syrian refugees who escaped the decade-long conflict taking place in their own country by crossing over the border).

The knock-on effects of Jordan's dwindling aquifers are extensive, ranging from soil degradation to widespread erosion and the loss of biodiversity and wildlife. The Azraq wetland area had been an important migratory station for thousands of birds, many of which were already endangered. The lack of water around the oasis has altered their migratory patterns.

Jordan's looming water crisis might seem too specific an example for most of us to worry about. But it is not occurring in isolation. From the Middle East to Asia and Latin America, Australia to Southern Europe, local water crises are all building up to a global one. When it comes to water, everything is connected.[iv]

Thirsty food and virtual water

Our food is thirstier than we are. Food production now accounts for 70% of all water used by humans, and for our own security, we need to better understand and manage the 'virtual' water hidden in what we eat.

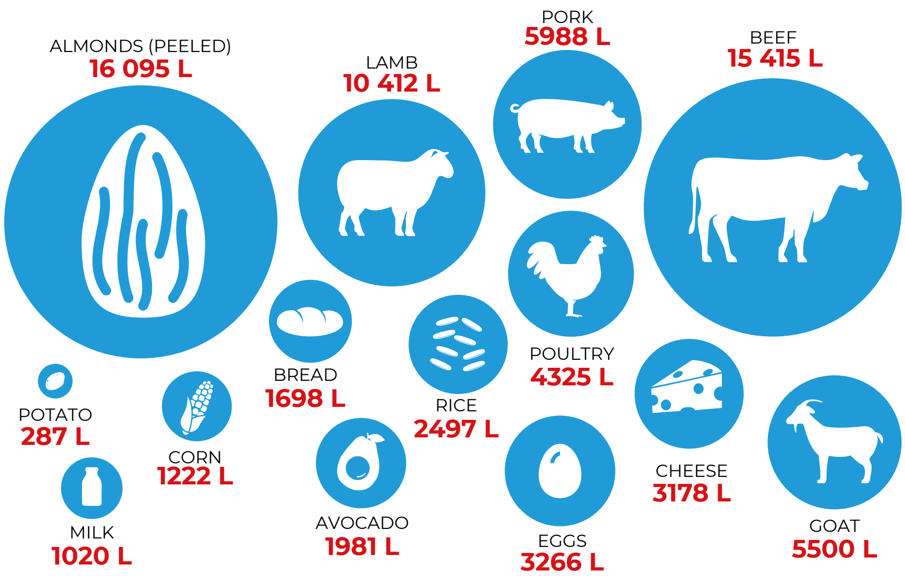
"In our bid to feed a growing global population, we have succeeded in producing ever greater amounts of food. In order to double the number of calories generated from the world's fields and farms, we have tripled the amount of water used in agriculture"

Although water covers most of our planet's surface and flows regularly through our daily lives, it is also an invisible resource, with vast quantities hidden in the food we eat. According to Seth Darling, a Fellow at the Institute for Molecular Engineering at the University of Chicago, it takes around 2500 litres of water to grow around 3 kilogrammes of alfalfa (a source of hay used as animal feed); from this portion, a cow will produce just 4 litres of milk.

Other foods are just as bad: it takes one and a half litres of water to produce a single grape, 22 litres to grow just one walnut, 113 litres to produce one potato and about 140 litres to grow the beans needed to make a single cup of coffee. Our food, in other words, is far thirstier than we are.

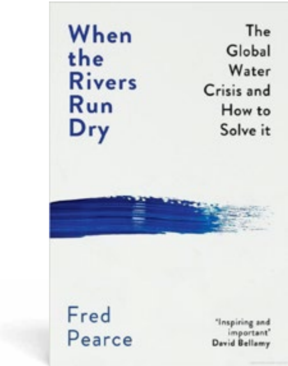
How Much Water Does It Take to Make 1 kg of Food?

Liters of water consumption per kilo of food



The water footprints of animal-based foods, and especially meat from ruminants, far exceed the footprints of plant-based foods.

DATA SOURCE: THE GREEN, BLUE AND GREY WATER FOOTPRINT OF CROPS AND DERIVED CROP PRODUCTS 2010, WATERFOOTPRINT.ORG; AND WATER FOOTPRINT NETWORK, WORLD RESOURCES INSTITUTE, WRI.ORG. ILLUSTRATION: AZOTE



What you eat is reflected in your individual water footprint. A typical western diet hides a huge virtual water consumption, concluded Fred Pierce, in his book When The Rivers Run Dry.

When the environment and science writer Fred Pearce, author of When The Rivers Run Dry, calculated his personal daily water use "as a typical meat eating, beer swilling, milk guzzling westerner," he discovered that although he only drank around three litres of water a day, the food he was consuming took his annual footprint to more than 100 times his body weight (which added up to half the contents of an Olympic sized swimming pool). His vegetarian daughter, he calculated, had around half his water footprint.[v]

Few of us see or think about how much water goes into our food; few package labels even list it as an ingredient, let alone disclose the amount used to produce the contents. For our future food security, it's important that we change that; we need to better understand how much invisible water is hidden in the production of our food.

We need to understand that in order to also understand the hidden trade in water. If, for example, it takes 1000 tonnes of water to produce a single tonne of wheat, and that grain is then exported to another part of the world, what is being shipped is not merely the wheat but, in effect, the water needed to grow it.

The term for this hidden quantity is 'virtual water'. First coined by Professor Tony Allen, of Kings College London, the phrase refers to the water in our lives that we don't drink directly or use for washing; the water embedded in the growing, rearing and processing of our food (as well as other household objects that are industrially produced). When you start to see the world through this lens, it becomes clear that the biggest exporters of commodity crops, such as the USA and Brazil, are not just trading in wheat, corn, rice and soy, but also in virtual water.

"Vast amounts of the world's water move around the planet through the global trade in food. For every tonne of wheat grown, harvested, and distributed, 1000 tonnes of water are used"

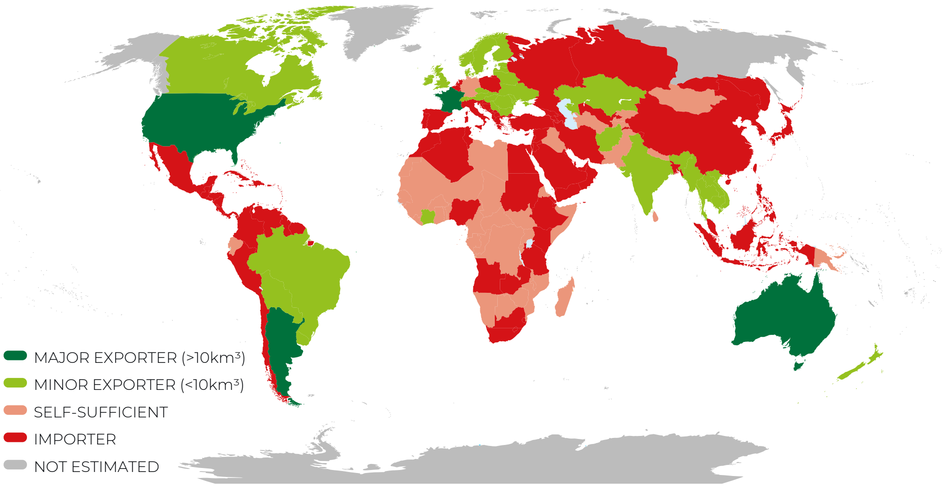
The flow of virtual water around the world has obvious benefits; it enables populations in water-stressed regions (such as Jordan, which imports more than 80% of its water in the form of food) to feed their populations through trade. However, this global trade is also creating a precarious situation in which water problems that are local can quickly become global. Wheat, rice and corn are among the world's thirstiest crops, and the USA's export of them contributes to the draining of its critical water reserves. If water problems there compel the US to reduce (or even halt) its food exports, our current, interlinked global food system will collapse. The impact on water-stressed countries, which are dependent on the flow of virtual water, will be especially severe.

Enhanced by a complex and vast irrigation system that depends on rain-fed underground water supplies, the Central Valley of California is one of the most fertile and productive places in the world. But starting in 2012, a prolonged drought devastated the region. More than 70% of water extracted in California goes to irrigation, so the drought was catastrophic for farmers. Hundreds of thousands of hectares of irrigated cropland had to be left fallow, at a cost of $2.2 billion to the economy and 17,100 jobs.

"The biggest exporters of commodity crops, such as the USA and Brazil, are not just trading in wheat, corn, rice and soy, but also in virtual water"

To mitigate the impact, the state government declared a State of Emergency that permitted farmers to extract more water from the Central Valley aquifer, at a rate far higher than could ever be replenished. The decision has had long term implications for Californians who depend on the aquifer, not just for agriculture, but also for day-to-day life in towns and cities. It also affects the many countries around the world that depend on food exports from the USA. For example, California produces 82% of the world's almonds, a harvest that comes from 800,000 acres of trees that cover 400 square miles. Seventy per cent of this crop is exported, with much of it going to the Middle East (the UAE is one of the top importers). In an increasingly globalised economy, the fortunes of an aquifer on the west coast of America have the potential to trigger wide-ranging shocks to food systems halfway around the globe.

Global Trading In Virtual Water



The biggest exporters of meat and commodity crops are also trading in virtual water.

DATA SOURCE: DATA AGGREGATED AND ADAPTED FROM INTERNATIONAL WATER MANAGEMENT INSTITUTE 2000, 2003, 2005 AND 2006.
ILLUSTRATION: AZOTE

How much water is there? Less than you think

H2O is one of the most common molecules on Earth, perhaps even the most common. But most of the planet's water is salty, toxic or inaccessible, and the scarce freshwater resources available to humans are increasingly under threat.

The Blue Marble. Apollo 17 hand-held Hasselblad picture of the full Earth. This picture was taken on 7 December 1972, as the spacecraft travelled to the moon on the last of the Apollo missions. The Earth is 12,740 km in diameter.

SOURCE NASA. PHOTO: NASA

"Of the mere 2.5% of all water on Earth that is fresh, around 80% is locked away in polar icecaps and glaciers, the great majority of which are located in Antarctica"

We famously live on a blue planet, a place which, when seen from space, appears awash in water. And it is indeed true that around three-quarters of the Earth's surface is covered by water, either as liquid or ice. Above this is yet more water in the form of clouds. In fact, H2O is one of the most common molecules on Earth, perhaps even the most common.[vi] So how can we be running short of something so seemingly plentiful?

The answer is that 97.5 % of the world's water is saltwater: undrinkable, corrosive, even toxic. Of the remaining 2.5 % that is fresh, around 80% is locked away in polar icecaps and glaciers, the great majority of which are located in Antarctica. About a fifth of all the Earth's freshwater lies below the surface – groundwater stored in aquifers (as we've seen in the cases of Jordan and California). Much of this groundwater is either unusable because it is contaminated with naturally occurring chemical elements such as arsenic or inaccessible because it is stored too deeply underground to be pumped out. The rest – the remaining 0.3 % of all fresh water – is what fills the planet's lakes, rivers and wetlands.

A significant portion of this fresh water is also out of reach, for it flows along parts of rivers like the Amazon, Orinoco and Congo that are inaccessible to humans.

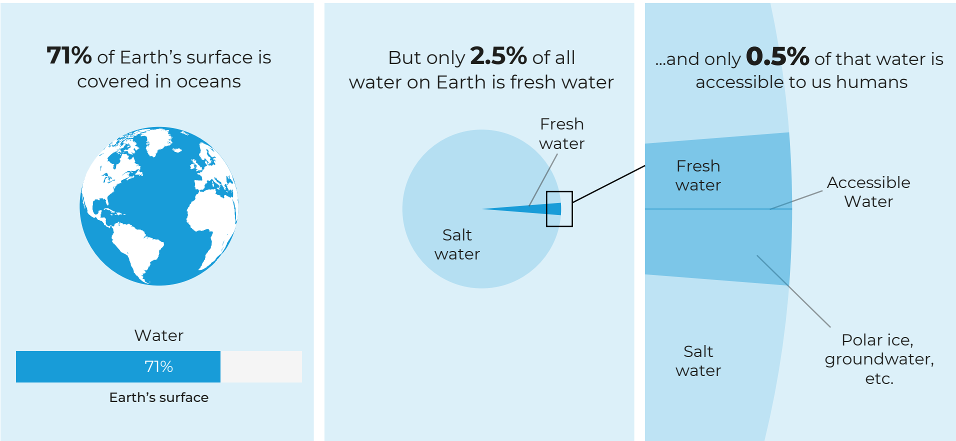
For all of these reasons, we start with a lot less water than most of us assume. And as we continue to extract and use more than can be replenished, we are coming up against the limits of what was once thought to be an inexhaustible resource.

"We have extracted – and are still extracting – more water from aquifers than nature can replace. Yet agriculture is not only a cause of water scarcity, it is also a victim of it. The tremendous quantities of water we suck from nature – a loan that cannot be repaid – renders the world's food supply increasingly vulnerable"

Along with land-system change, biodiversity and climate change, freshwater use is one of the planetary boundaries – those lines that demarcate the safe operating space for humanity – described by environmental scientist Johan Rockström. As Rockström and his team explained, crossing these boundaries may generate unacceptable environmental change, potentially endangering human existence itself. Human activity, including food production, has led to increasing risks of us pushing through this particular boundary.[vii]

The factors driving us out of a safe operating space are complex and interconnected, ranging from over-extraction and the diversion of water that would otherwise replenish lakes and aquifers to irrigation, pollution (e.g. agricultural run-off contaminating freshwater supplies), and biogeochemical flows (such as the transfer of phosphorous from soil to rivers and onto the oceans). The draining of wetlands for agricultural production and urban development is also part of our looming water crisis. The corrosive effect of all of this human activity on the water cycle is further exacerbated by climate change and global warming, which bring unpredictable weather patterns, floods and droughts. And so, every drop of freshwater we have is precious.

Water on the blue planet



The proportion of the Earth's water that is accessible to us humans is vanishingly small – and still, we waste it.

DATA SOURCE: WORLD BANK. ILLUSTRATION: AZOTE

In 2018, extreme water shortages nearly pushed Cape Town to "Day Zero" – the day in which the municipal water supply would run entirely dry. And the South African city is hardly alone. In Chennai, India's sixth largest city, reservoirs have already run dry; in Rome, authorities were forced to begin rationing water. These are not isolated, local incidents, but pieces of one big jigsaw puzzle that potentially add up to a global water crisis. Unless we make radical and systemic changes to our food system, the world will see more and more communities facing their own Day Zero.

The world's largest waterfall, the Victoria Falls, on the border of Zambia and Zimbabwe in Southern Africa, was reduced to a trickle during the severe drought in 2019.

PHOTO: GETTY IMAGES

Food revolutions — from Green to Blue

The technical breakthroughs of the Green Revolution in the 1960s and 1970s were supremely successful in increasing the supply of food and averting starvation. But the 'supercrops' that were the Revolution's hallmark coupled with the increase in production required far more intensive use of water resources.

The recent transformation of the global food system has meant that in some parts of the world up to four times as much water is being extracted each year than in the 1960s, from both above and below ground sources.

The technical breakthroughs of the so-called Green Revolution of the 1960s and 1970s were supremely successful at increasing the supply of food and averting starvation; populations doubled in the space of thirty years as this agricultural boom unfolded around the world. Much of this success was due to genetic breakthroughs (the creation of novel, high-yielding crops) and chemical inputs (the use of vast amounts of artificial fertiliser and pesticides) that enabled these new plant varieties to grow. But the story of the Green Revolution was also about water.

"Rice requires about four times as much water to cultivate as pulses or vegetables, so a Blue Revolution might well encourage farmers to supplant one crop with another"

The 'super crops' developed in the Green Revolution often replaced lower-yielding but less water-dependent varieties. The wheats bred by Norman Borlaug and rice varieties issued by the International Rice Research Institute, both of which were distributed widely, required far more intensive use of water resources, particularly from groundwater supplies. Along with the new seeds and chemicals they received, communities that had previously farmed using only surface water were given the technology to pump water from deep beneath the soil.

The water legacy of the Green Revolution is complicated, and it varies widely by location. In regions with well-managed irrigation systems that used fertilisers carefully, the faster-growing, higher-yielding crops had the potential to produce more calories per unit of water. In reality, many of the new irrigation systems weren't efficient, and relied on the flooding of entire fields, a practice that continues to this day. In these cases, the rise in water use outstripped the rise in food production.

More sweepingly, the Green Revolution changed the nature of growing and distributing food. Farmers became locked into commodity markets in which success was measured not in terms of the nutritional value of what they produced, but sheerly by quantity. The abundance of grain generated by the new technologies also made it possible for ever greater proportions of the global crop to be fed to animals for meat and dairy production, as opposed to human consumption. It's this systemic shift in patterns of production and consumption that is the Green Revolution's true water legacy.

India's experience illustrates this process. In the space of a few decades the country was transformed from a nation at risk of famine to one that not only enjoyed greater levels of self-sufficiency, but produced enough of a surplus to become a major rice exporter. When it comes to water, however, this transformation came at a high price. With half of its crops now irrigated by underground water, India's aquifers are emptying rapidly, and its river networks depleting. It has become another example of a country that bases its food production on borrowed water, and borrowed time.

The city of Chandigarh, in the north-western state of Punjab, lies in the heart of India's grain basket and is part of the region that took a lead role in the country's Green Revolution, when new, highly productive varieties arrived in the 1970s. Land under rice paddy cultivation increased seven-fold and areas planted with wheat more than doubled.[viii]

Planted with these new crops, three-quarters of Punjab's agricultural land now depends on groundwater irrigation. But that resource is declining rapidly, with water levels dropping 40 to 50 cm each year.[ix] Wells are running dry, even as desperate farmers drill down more than sixty metres in search of untapped reserves. With so much of the region's food supply dependent on this vanishing source of water, Punjab's food security is at risk.[x] And yet, just as in the case of California, Punjab is also a food exporting region; through its supplies of wheat and rice, it is a net exporter of virtual water.

Agriculture workers planting rice in a paddy in the Sangrur district of Punjab.

PHOTO: GETTY IMAGES

For Punjab, the only way to secure water reserves for the future is to dramatically change its food system. Some refer to the necessary transition as a "Blue Revolution" – a new era of farming and food production aimed at conserving and managing freshwater supplies in far better ways than the Green Revolution's legacy allows. It will demand not just an agricultural transformation but also a political, cultural and economic one.

The chemical element that poses the greatest threat to freshwater is also one of the most valuable for agriculture: nitrogen. Around half of all nitrogen fertiliser used in agriculture leaches into water or the air. When nitrogen enters rivers, lakes and oceans it can fertilise vast blooms of algae that deplete oxygen and create dead zones"

Rice, for example, requires about four times as much water to cultivate as pulses or vegetables, so a Blue Revolution might well encourage farmers to supplant one crop with another. Getting farmers to make the switch away from a lucrative crop is complicated, but institutions like India's state-sponsored Public Distribution System, which gives the national government powerful economic levers to change its food system, can help. Currently, the PDS buys staple foods (mostly wheat and rice) worth $2.25 billion a year to sell at a subsidised price to about 160 million families. More generous subsidies to less thirsty crops could help conserve some of India's fragile water supplies by diversifying the country's food system.[xi]

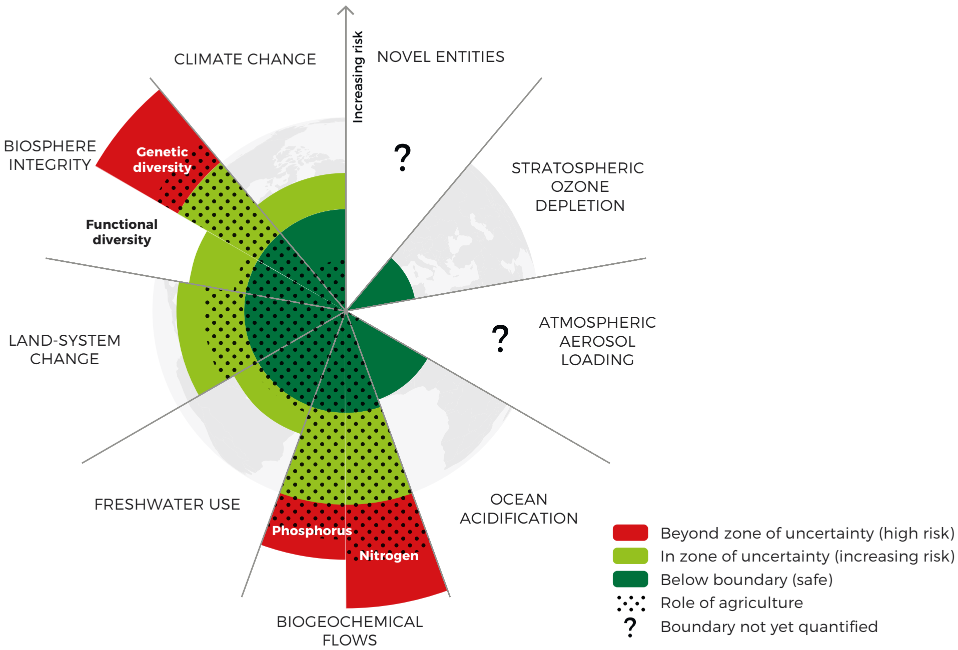
The Green Revolution not only affected the quantity of water used in global food production, but also the quality of water it has left behind. Farms today discharge large quantities of agrochemicals, organic matter, drug residue, sediment and saline drainage into bodies of water. In most high-income countries and many emerging economies, agricultural pollution has overtaken contamination from urban areas and industry as the major factor in the degradation of inland and coastal waterways. In the European Union, more than a third of all bodies of water are under pressure from agricultural pollution, and in the United States and China, agriculture is the main source of pollution in rivers.[xii] The chemical element that poses the greatest threat to freshwater is also one of the most valuable for agriculture: nitrogen.

The World Bank describes nitrogen fertiliser as both a boon and a curse.[xiii] Though essential for crop growth, its supply – at least in its naturally-occurring form – is limited. At the beginning of the 20th century, scientists Fritz Haber and Carl Bosch discovered how to convert atmospheric nitrogen (from the air) to make synthetic fertiliser from ammonia. This discovery changed the world and has sustained billions of lives thanks to the increased food production it made possible. But because around half of all nitrogen fertiliser used in agriculture leaches into water or the air, it has also had a grave environmental impact.[xiv]

When nitrogen enters rivers, lakes and oceans it can fertilise vast blooms of algae that deplete oxygen and create dead zones in which few lifeforms can survive. In freshwater supplies, nitrogen can also transform into nitrates, a compound, known to stunt growth, that poses great risks to children's health. In its 2019 report, Quality Unknown, The Invisible Water Crisis, The World Bank emphasized that 'the vast subsidies accruing to fertilisers likely generate damage to human health that is as great as, or even greater than, the benefits that they bring to agriculture'.[xv]

What's more, among the nine planetary boundaries that help outline a safe operating space for humanity, one that has been radically changed by humans are the biogeochemical cycles of nitrogen and phosphorus (the two most important components in chemical fertiliser).

The crossing of this boundary through the production and application of fertiliser has been disastrous for ecosystems and food security. Fertiliser carried along river systems from the intensive agriculture belt of the American Midwest, for example, has created a 'dead zone' in the Gulf of Mexico that has undermined fisheries and reduced catches.[xvi] It's another case in which food production is both cause and victim of our water problems.



Estimates of how the different control variables for seven planetary boundaries have changed from 1950 to present. The green shaded polygon represents the safe operating space.

DATA SOURCE: CAMPBELL ET AL. 2017 BASED ON ROCKSTRÖM ET AL. 2009

Freshwater habitats in peril

The expansion and intensification of agriculture has turned freshwater habitats into some of the most threatened ecosystems on earth. When water levels decline, so too do employment, living conditions, and human health.

The arid landscape of the former Aral Sea, deprived of its water by mega-farms that cultivate cotton, wheat and rice. PHOTO: GETTY IMAGES

"There were no fish in the Soviet Union like the fish in Aral," former residents of one of the old fishing ports told the BBC in 2015

The 20th century witnessed an engineering revolution as well as an agricultural one. The proliferation of mega dams, vast reservoirs and extensive canals gave us physical structures capable of controlling flows of water along the world's largest and most powerful rivers, from the Colorado to the Zambezi. This has been both a blessing and a curse to people and to our planet. Dams, for instance, generate one-sixth of the world's electricity and irrigate one-seventh of all food crops.[xvii] But their construction has flooded vast amounts of land, displaced a population greater than France's, and turned freshwater habitats into some of the most threatened ecosystems on earth. And while dams, reservoirs and canals have played a critical role in the greatest agricultural booms, they have also busted the fortunes of fisheries, farmers and communities downstream.

One of the most dramatic illustrations of this double-edged sword is the Aral Sea in Central Asia. One of the world's largest freshwater lakes, the Aral once stretched across the borders of Kazakhstan and Uzbekistan, and until the 1960s, covered an area the size of Belgium and the Netherlands combined. In the early years of the Soviet Union, it was famous for its stunning blue waters and picturesque beaches, its abundance of fish and bustling fishing ports.[xviii] Today, 90% of the lake is gone, replaced by an arid landscape. What little water remains is now so salinated that most life forms cannot survive in it. The UN considers the loss of the Aral Sea one of the "greatest environmental disasters of the twentieth century."[xix]

"Fifty years ago, the Aral Sea was one of the world's largest fresh-water lakes. Today, 90% of it is gone. What little water remains is now so salinated that most life forms cannot survive in it"

Satellite images show that this once immense lake is now reduced to two narrow pools; and although the fish are gone, some of the old ships that used to ply the Aral's waters can still be seen – surreal, isolated, rusting wrecks that seem inexplicably stranded in miles of desert. It's one of the most graphic examples of what can happen when humans ruthlessly attempt to override nature.

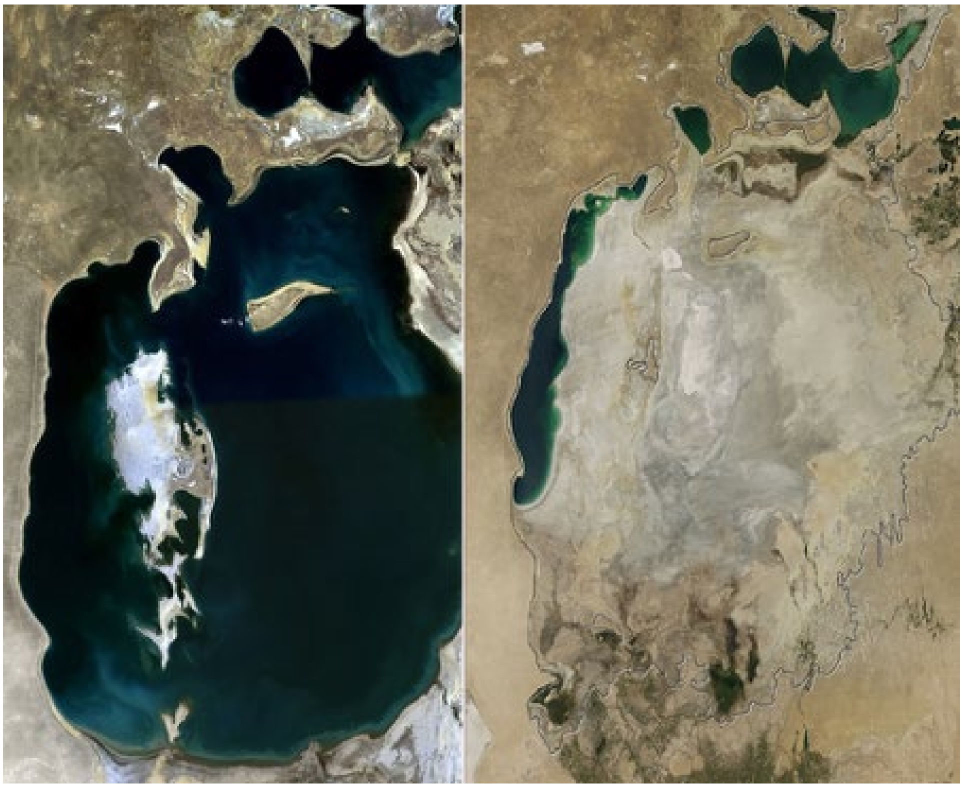
Before unsustainable irrigation and unwise agricultural practices destroyed it, the Aral Sea was fed by two great rivers of Central Asia: the Amu Darya, which flowed out of the snow-capped Hindu Kush in Afghanistan, and the Syr Darya, which originated in the Tian Shan mountains that run through Khazakhstan and into China. But when Soviet engineers started building ever more ambitious projects to divert water from these rivers through canals and into new agricultural projects – particularly rice and cotton cultivation – the Aral Sea began, year by year, to shrink.

After the collapse of the Soviet Union, the situation worsened, as newly independent states raced to expand their economies, and in the process diverted even more water from the Aral Sea. By the time science writer and water expert Fred Pearce returned in 2014 to a place he once knew as fertile, all he found was *"a landscape of poison, disease and death."*[xx]

Irrigating crops with fresh water from the Amu Darya and the Syr Darya rivers was itself nothing new. In the 19th century, the rivers provided a source of water for vast orchards, vineyards and fields of grain – but extracted at a rate that didn't compromise the health of the Aral Sea. Soviet strategy in the 1960s, however, was a different story. The creation of huge farms devoted to growing some of the world's thirstiest crops (rice, wheat and cotton) in land that was arid initiated the tragic, manmade decline of the Aral Sea. By the turn of the century, the sea had lost more than half of its surface area, exposing nearly 30,000 km^2 of the lakebed.[xxi] In the dwindling water, salts and minerals became more concentrated, killing off fish stocks. [xxii]

At the beginning of the farming boom of the 1960s, the Aral was one of the Soviet Union's largest commercial fisheries, serviced by massive ships employing thousands of fishermen and bringing in more than 40,000 tons of fish each year. Thousands more were employed in the Aral's processing plants, canneries, and railroad yards, where tonnes of fish left daily for markets in Moscow. There were 19 villages and two cities on the sea – home to thousands of people. About 20% of all the fish consumed in the Soviet Union came from the 20+ species caught in the Aral Sea.

"There were no fish in the Soviet Union like the fish in Aral," former residents of one of the old fishing ports told the BBC in 2015. But as the lake shrank, it receded from the harbours, forcing fishermen to extend the ports by digging deep canals, and then later – in a final desperate measure – to use helicopters to get their catch to the processing plants. Eventually, the fish disappeared altogether.



Views of the Aral sea in 1989 and 2014. PHOTO: NASA

When filmmaker Isabel Coixet arrived at the Aral Sea in 2009 to shoot a documentary highlighting this unfolding water crisis, the lake had lost surface water equivalent to the size of Ireland and its volume had been reduced to a quarter. A human tragedy was also unfolding. By the early 2000s the region had the highest infant mortality rate in all of the former USSR, and levels of chronic disease that far exceeded all averages. The landscape had turned hostile. As the sea shrank, it could no longer act as a vast climate buffer, so summers got hotter and winters colder. The exposed salt flat was infused with pesticides from more than half a century of agricultural run-off. Violent dust storms blew clouds of salt, sand and chemicals into the air, and into people's lungs.

Despite the tragedy of all of this, however, there are reasons for optimism – and perhaps a renewed faith in how we can better control and manage the movement of water. By building new dams to protect river flows into the lake and by improving irrigation systems to conserve water, levels are rising again in the North Aral and salinity levels are dropping. So much so, in fact, that fish have begun repopulating the sea. We can help nature bounce back.

A warning from the rivers: the salmon's decline

Perhaps no species better illustrates the damage we have done to aquatic habitats than the wild Atlantic salmon. The migrating fish, crucial to the functioning of ecosystems throughout the Atlantic and the two thousand rivers flowing into it, is under grave threat.

"Salmon are the perfect metaphor for everything we are doing wrong to the planet," says Mark Kurlansky, author of Salmon: A Fish, the Earth, and the History of their Common Fate. In his work, he traces the relationship between increased human impact on rivers and oceans and a dwindling salmon population. To save the fish, all we need to do, he said in a radio interview exploring this issue, is, "stop destroying the Earth. That's all." And that means restoring the health of our rivers.

The wild Atlantic salmon is a keystone species, crucial to the functioning of ecosystems throughout the Atlantic and along the two thousand rivers in Europe and North America that flow into that ocean. It is also an animal under dire threat. As such, it represents a powerful warning about the damage we have caused to freshwater systems around the world.

Wild salmon has a wide geographical range. In the west, the fish come down from Ungava Bay in Canada and travel across Lake Ontario to Connecticut. From the east, they swim from rivers in Ireland, England, Scotland and Wales; the Rhine in Germany, the Rhone in France and the tributaries of the Russian White Sea. From the south, they head out from rivers along the coast of Portugal.

Salmon returning to their birthplaces for spawning is one of the greatest natural migrations on the planet. PHOTO: GETTY IMAGES

Salmon start life in rivers. When they're big enough, they undergo an astonishing physical transformation that enables them to swim from their freshwater river homes to saltwater feeding grounds in the seas around Greenland and the Faroe Islands. After one or more years, the fish leave what would have once been a massive congregation and return inland, finding their way back to their starting place, leaping up the rivers they left years before, completing one of the greatest natural migrations on our planet.

But in the last half a century, salmon numbers have declined at an alarming rate. Approximately 1.8 million salmon used to return each year to Ireland's rivers, for example, in the 1970s. But this number, as with all stocks around the Atlantic, has plummeted by as much as 70%.[xxiii] "Something is going wrong in our oceans," says Ken Whelan, a marine biologist for the Atlantic Salmon Trust. "And something quite massive has also happened to our rivers."

"In the 19th century, salmon were caught in oceans and rivers by the millions; they were considered so abundant, that they were ploughed into soil as fertiliser. Now they are becoming an endangered species"

In the 19th century, salmon were fished out of the oceans and rivers by the millions; it was considered so abundant, the fish was ploughed into the soil as fertiliser. More recently, climate change and warmer seas have diminished and displaced populations of the salmon's food, which includes zooplankton. Aquaculture has also caused problems for the wild fish, contaminating them with sea lice and compromising their gene pool with DNA from farmed salmon that have escaped their pens. But nothing has had a worse impact on wild salmon than the declining health and quality of our rivers.

Following industrialisation in the 18th century, larger dams and mills disrupted rivers to such an extent that many ancient populations of salmon went extinct. Their runs up and down rivers, which had evolved over thousands of years,

Hydroelectric dams lock waterways. Glen Canyon Dam, Colorado River, Arizona, USA.

PHOTO: GETTY IMAGES

"Following industrialisation in the 18th century, larger dams and mills disrupted rivers to such an extent that many ancient populations of salmon went extinct. Among the communities that lived along these rivers, even the memory of salmon soon died out"

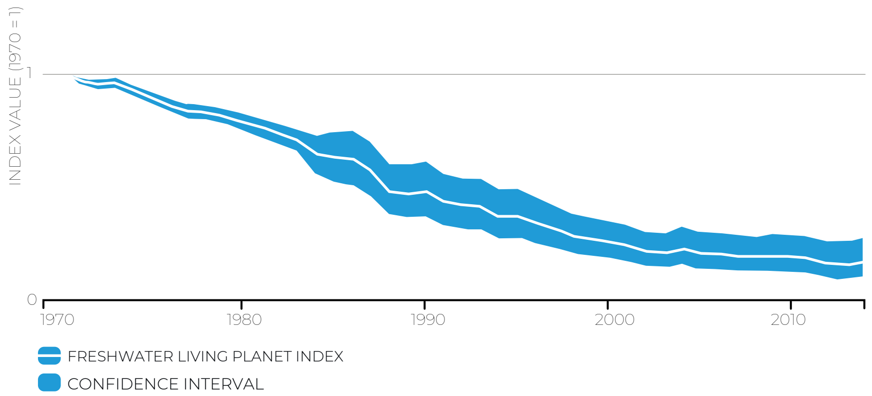
became impassable; no matter how hard they tried or how high they leapt they couldn't overcome the manmade obstacle course. Among the communities that lived along these rivers, even the memory of salmon soon died out.

After hydroelectric dams were built in the 1950s along the Delana River (a tributary of the Sullane River which in turn is a tributary of the River Lee) in County Cork, the salmon disappeared, no longer able to make the journey back to their place of birth. When one fisherman reported seeing two of the species in 2016, it was significant enough for a newspaper to report the story – the first sighting of salmon in the river for more than fifty years.[xxiv]

In Scotland's River Spey, centuries of water extraction – including, in the 19th century, distillery weirs built by the whisky industry – contributed to the decline of stock in what was once one of the world's great salmon rivers. The populations that remained were further depleted by industrial pollution.

The freshwater living planet index: 1970 to 2014

The Freshwater Living Planet Index shows an 83% decline in numbers for 880 freshwater species that were monitored between the years 1970 and 2014 in 3,358 locations across the globe.



In the 20th century, around the Atlantic, agricultural runoff killed off yet more life in rivers and, along with it, millions more wild salmon. Efforts to restore rivers across Europe started in the 1960s, with reductions in heavy industry and the banning of some agricultural pesticides. But even while these new measures were being implemented, another practice emerged to threaten salmon stocks. To make way for the larger farms of modern agriculture, woodland was cleared and trees – including those that line riverbanks – cut down. The roots of trees not only help bind riverbanks together and prevent erosion but are a source of the insects that salmon eat, and protect the gravel beds where the fish spawn. Fallen trees also help create habitats in which small fish can hide and grow. Salmon populations will never bounce back to their original numbers unless more of the woodland and forests that once bordered rivers are replaced. We are only starting to realise that the loss of trees to agriculture has even greater consequences for future freshwater supplies than we ever imagined.

When we lose trees, we lose rainmakers

It is well known that the clearing of millions of acres of tropical forests for palm cultivation and other agriculture resulted in a tragically massive loss of biodiversity. But we are only now learning about the catastrophic effects it has also had on the global water cycle.

Around the same time that irrigation began to suck dry the Aral Sea, another water problem was developing 7000 kilometres away. In Borneo, it was not the direct extraction of water that created the dilemma, but the clear cutting of forest. Across Asia in the 1960s, the demand for wood from western economies sparked one of the most intense logging efforts in history. Among the forests most affected were those in Indonesia where, within the space of two decades, more than a quarter of the archipelago's trees were cut down.[xxv]

Driven by the global food industry's growing appetite for palm oil, even more deforestation took place in Asia during the 1980s. By the end of the decade, Malaysia had replaced 2.5 million acres of forest with this commodity crop.[xxvi] Indonesia followed Malaysia's lead on palm oil, with a boom that has resulted in

The natural water cycle

Water makes life go 'round. The largest forests, such as those found in Borneo and the Amazon, act as rainmakers; their trees effectively pull moisture from the clouds and recycle it. When we lose forests, we also change the global water cycle.

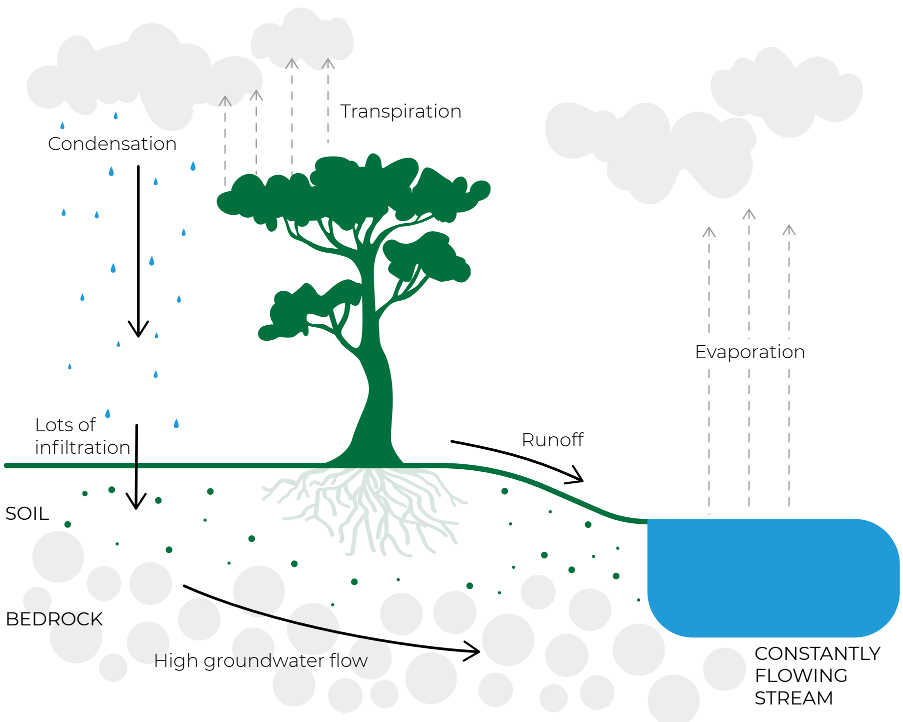


ILLUSTRATION: AZOTE

Moisture produced by the world's forests generates rainfall thousands of miles away.
PHOTO: GETTY IMAGES

"People once said that rainforests had high rainfall because they were located in wet parts of the world. Now it looks like forests usually make their own rainfall"

DOUGLAS SHEIL,
FOREST SCIENTIST AT THE NORWEGIAN UNIVERSITY OF LIFE SCIENCES

the clearing of 30 million acres (an area three times the size of Switzerland) for palm cultivation. The planting came mostly at the expense of the Bornean and Sumatran forests.

It's well known that this period in agricultural history resulted in a tragically massive loss of biodiversity. But we are only now learning about the catastrophic knock-on effects it has also had on the global water cycle. *"People once said that rainforests had high rainfall because they were located in wet parts of the world,"* noted Douglas Sheil, a forest scientist at the Norwegian University of Life Sciences, in 2019. *"Now it looks like forests usually make their own rainfall."*

Vegetation on land, and in forests in particular, provides the primary source of moisture for vast tracts of the world. The largest forests, such as those found in Borneo and the Amazon, act as rainmakers; their trees effectively pull moisture from the clouds and recycle it. Without trees, this cycle is compromised, and much of the rain that would normally fall on these huge continental areas disappears.[xxvii]

In the Amazon, even partial deforestation can lead to significant reductions in rainfall, which harms not only the rainforest itself but land thousands of kilometres downwind in southern Brazil, Paraguay, Bolivia, Uruguay and Argentina, where former forests have been cleared to grow soya, maize, coffee and sugar. In a twist of irony, rain shortages caused by deforestation are having a serious effect on the cause of the deforestation itself, which is agriculture.

For too long, the climatic impact of deforestation has been calculated purely in terms of the extra carbon dioxide it releases into the atmosphere. Now, however, we understand that deforestation, driven by agriculture, is also part of the growing global water crisis. During a long drought in 2015, when the city of São Paulo nearly ran out of water, municipal authorities blamed the knock-on effects of deforestation.[xxviii] The water returned, and São Paulo's 12 million inhabitants narrowly escaped a dire fate. But history tells us not all cities have survived water crisis.

The largest forests, such as those found in Borneo and the Amazon, act as rainmakers; their trees effectively pull moisture from the clouds and recycle it.

Water warnings from history: the fall of civilisations

We don't need a crystal ball to find out what will happen if we don't succeed in managing the world's freshwater resources better. We just need to look back in history for valuable lessons.

History offers valuable lessons on how water stress and drought can decide the fate of civilisations. One of the most famous examples comes from the Maya, the once-great Central American civilisation that, in the 9th century, was nearly destroyed, most likely by severe drought.[xxix] Within the span of a century, this advanced society went from prosperity to collapse, its culture devastated and its population decimated. Historians have debated the causes, but recent analysis suggests water shortages dealt the fatal blow to the Maya. Advanced irrigation technology helped them flourish even during periods of drought. But according to Linda Kuil, an expert in water resource systems at Vienna University of Technology, this success also helped sow the seeds of catastrophe. The sophisticated water reservoirs the Maya developed enabled them to build a city that exceeded their own environmental bounda-

Mayan and Aztec agriculture built on sophisticated engineering and elaborate water management. Mural painting at the Museo Nacional de Antropología, Mexico.

ries, but it depended on an unsustainable agricultural system. In other words, the reservoirs allowed the Maya to continue 'business as usual' – and for their population to continue to grow – even during periods of drought. Perhaps they became complacent, placing far too much confidence in the power of their own technology to overcome any shortages that nature threw at them. But when a serious and prolonged drought did arrive, the depleted reservoirs couldn't save them; the civilisation and its farming practices simply weren't resilient enough.

For Kuil, the Maya's experience offers an important lesson for today. *"We need to be more careful with our natural resources,"* she writes. *"If technical measures simply deal with the shortage of resources on a superficial level and we do not adjust our own behaviour, society is left vulnerable."*

The sophisticated water reservoirs the Maya developed enabled them to build a city that exceeded their own environmental boundaries and depended on an unsustainable agricultural system.

Crises, conflicts and water wars

Water stress is a main source of conflict in many parts of the Middle East and Central Africa, where climate change adds to the frailty of freshwater resources. Lack of water brings famine, provokes war and drives migration.

In February 2012, the U.S. intelligence community produced an assessment of global water security that predicted freshwater supply would fall short of demand in the coming years if water management was not improved. The over-extraction of groundwater and contamination of freshwater sources could not only threaten national and global food markets but — when compounded by poverty and civil unrest — might also provoke social disruption and state failure. Likely candidates for this scenario, according to the report, include North Africa, the Middle East and South Asia. And it is only one piece in a growing body of evidence that suggests that when water starts to run dry, the potential for conflict increases.[xxx]

Many experts now believe the Syrian civil war, which has left more than 400,000 people dead, was triggered by water stress. Between 2007 and 2010, Syria experienced one of the worst droughts in recorded history. It decimated rural communities and drove hundreds of thousands of Syrians off the land and into cities, where they were marginalised. The resulting tensions climaxed in street demonstrations in the spring of 2011 that prompted a brutal crack-down from the government of Bashar al-Assad.[xxxi]

Water stress and food insecurity can drive conflict and migration in Africa and the Middle East.

PHOTO: GETTY IMAGES

"Large-scale migration to Europe from sub-Saharan Africa has also been triggered by lack of water for crops and livestock. Northern Nigeria, Chad, Niger and Mali are among the most affected countries"

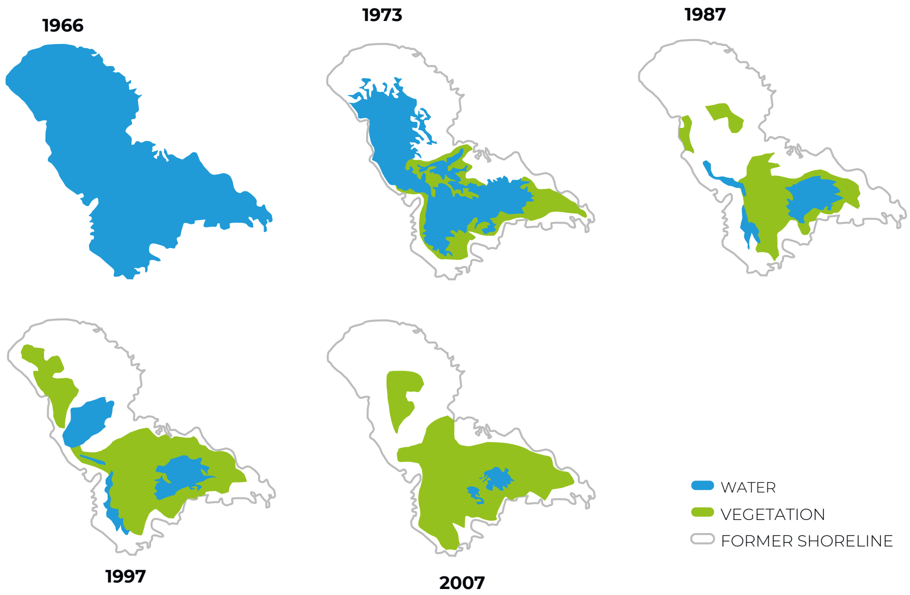
Anders Berntell, executive director of 2030 Water Resources Group, has also suggested a link between water stress and the rise of Boko Haram and Al-Shabaab. Young people, he argues, realise that, as a result of depleted natural resources, including land and fresh water, there are few economic opportunities open to them, leaving them vulnerable to radicalisation. *"There is no future for them,"* says Berntell. *"They become easy targets."*

Lack of water for crops and livestock has also triggered large-scale migration to Europe from sub-Saharan Africa. Northern Nigeria, Chad, Niger and Mali are among the most affected countries.

If we want a more stable world, we need to take urgent action to bring greater stability back to the world's freshwater supplies. We need transformative ideas for our food system that will make better use of freshwater, the world's most coveted resource.

LAKE CHAD

Lake Chad is almost exhausted as a combined effect of agriculture pressure and climate change.



DATA SOURCE: MAPS SOURCED FROM NASA SATELLITE IMAGES. HTTPS://EARTHOBSERVATORY.NASA.GOV/FEATURES/LAKECHAD
ILLUSTRATION: AZOTE

Five ideas for future farming & water friendly food

The 2015 Stockholm Water Prize Laureate, Mr Rajendra Singh.

SOURCE: SIWI STOCKHOLM INTERNATIONAL WATER INSTITUTE

1. Respect tradition

Rajendra Singh and the power of johads. In 1985, a young Indian graduate, Rajendra Singh, arrived in a small village in Rajasthan's Alwar district with an ambition to build clinics so he could improve the health of the rural population. But when he got there and observed traditional communities at work, he was inspired instead to help revive an ancient water-saving technology, the johads, that was in danger of disappearing. Large, crescent-shaped dams made of earth and rocks, johads date back more than 3000 years, and were used to both store the runoff from monsoon rains and channel water back into the ground to replenish the water table. Three decades later, Singh has overseen community initiatives that have built nearly 9000 johads and restored water supply to 1,000 villages.[xxxii]

2. Drip, don't pour

Among the many schemes around the world designed to help farmers reduce their water footprint is Zimbabwe's Sizimele-Action for Resilience Building. The project encourages more diverse and sustainable farming practices among 30,000 vulnerable households, many of whom have been hit hard by prolonged drought. It enables farmers to reduce their dependency on inefficient flood irrigation (which not only wastes water but also washes away nutrients in the soil and fertilisers) by instead adopting targeted drip irrigation, which uses underground pipes to protect water supplies and prevent crop failure.[xxxiii]

3. The salt solution

The world's desalination plants, which convert seawater into drinking water and water for agriculture, currently supply around 70 million cubic meters per day. That quantity must increase if we are to meet the demands of a growing population, but desalination in its present form, which depends heavily on oil and gas, comes with high environmental costs. The British company, Solar Water, believes it has the solution: carbon-neutral, fossil-fuel free desalination, powered by the sun. Its new technology is being installed in the Saudi Arabian city of Neom, where seawater from the Red Sea will be the primary source of water.[xxxiv]

4. Grow more water-friendly crops

New technologies can buy us time, but for a truly water-secure future, we need to think far more ambitiously about food and farming practices. What we grow and what we eat has to change. Researchers at the Data Science Institute at Columbia University have calculated that countries in south Asia could enhance the sustainability of food production if farmers plant less rice and replace the crop with more nutritious and environmentally-friendly ones, like finger millet, pearl millet and sorghum. By diversifying crops, countries such as India can strengthen their climate resilience without reducing calorie production or requiring more land.[xxxv] In western economies, reducing meat consumption and increasing legume cultivation can achieve the same effect.

5. Don't waste food; think about all that virtual water:
Each of us can make a contribution to solving the global water crisis. The most simple and immediate action we can take is to not waste food. We know that 70% of the water humans use globally is consumed by agriculture, and we also know that one-third to one-half of the world's food supply – an estimated 1.3 billion tons – is simply lost or wasted every year. The less food we waste, the more water we save. But understanding our own water footprint is essential, too. By becoming aware of the virtual water in the different foods we eat, we can make more informed choices about the impact of our diets on water use around the world. Our local decisions have the power to add up to a global solution.

The less food we waste,
the more water we save.

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THE
CURT BERGFORS
FOOD
PLANET
PRIZE

The Curt Bergfors Food Planet Prize aims to identify and reward initiatives and projects that can contribute to reshaping the food system all around the world.

Two prizes of $1 million each will be awarded annually, starting in 2020. One prize will go to an existing solution that can be scaled quickly for a global impact. The second prize will go to a radically innovative project that can sustainably transform parts of the food system. The nomination process is currently open.

The Curt Bergfors Foundation was founded in 2019 to support the transition to resilient food systems that protect both people and the environment.

To ensure free and independent research in the field, the foundation is funding a new professorship at the Stockholm Resilience Centre, Stockholm University: *"The Curt Bergfors professorship in sustainability science with a focus on sustainable food systems."* The funding over ten years corresponds to a donation of SEK 20 million.

The foundation is capitalized with half a billion SEK from Curt Bergfors' private assets. It will continuously take new initiatives to contribute to resilient food sourcing and a responsible food culture.

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