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An algae bloom in Lake St. Clair in July 2015. The lake is bordered by Detroit, Michigan to the west and Canadian farmland to the east. NASA/NOAA

ANALYSIS

The Nitrogen Problem: Why Global Warming Is Making It Worse

New research shows that increases in rainfall and extreme weather because of climate change will increase the amount of nitrogen polluting rivers and other waterways. The findings underscore the urgency of reforming agriculture to dramatically reduce the use of nitrogen fertilizers.

BY RICHARD CONNIFF • AUGUST 7, 2017

It is a painful lesson of our time that the things we depend on to make our lives more comfortable can also kill us. Our addiction to fossils fuels is the obvious example, as we come to terms with the slow motion catastrophe of climate change. But we are addicted to nitrogen, too, in the fertilizers that feed us, and it now appears that the combination of climate change and nitrogen pollution is multiplying the possibilities for wrecking the world around us.

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A new study in *Science* projects that climate change will increase the amount of nitrogen ending up in U.S. rivers and other waterways by 19 percent on average over the remainder of the century – and much more in hard-hit areas, notably the Mississippi-Atchafalaya River Basin (up 24 percent) and the Northeast (up 28 percent). That's not counting likely increases in nitrogen inputs from more intensive agriculture, or from increased human population.

Instead, Stanford University researcher Eva Sinha and her co-authors simply took historical records of nitrogen runoff as a result of rainstorms over the past few decades, recorded by the U.S. Geological Survey. Then, assuming for the sake of argument that there will be no change in the amount of nitrogen being added to the environment, they calculated how much additional nitrogen would be leached out of farm fields and washed down rivers solely because of extreme weather events and increased total rainfall predicted in most climate change scenarios. The bottom line: "Anticipated changes in future precipitation patterns alone will lead to large and robust increases in watershed-scale nitrogen fluxes by the end of the century for the business-as-usual scenario."

Lakes and other freshwater bodies now routinely face toxic blue-green algae blooms that are fueled by nitrogen pollution.

But the business-as-usual scenario is of course already in trouble, even without climate change. Headlines have tended to fixate on the Gulf of Mexico "dead zone" produced by nitrogen flushed down the Mississippi River from the cornfields of the upper Midwest. (This year's "dead zone" is the largest ever, the National Oceanic and Atmospheric Administration announced last week.) But the problem is already much broader than that, says senior author Anna M. Michalak, also of Stanford, citing a series of recent incidents caused by nitrogen pollution. Last summer, for instance, a 33-square-mile algae bloom caused Florida to declare a four-county state of emergency. Another closed the Dungeness crab fishery along half of the Washington State coast last year and affected other fisheries as far south as Mexico.

The combined effect of climate change and nitrogen pollution is also evident on inland waterways, according to Hans Paerl, an aquatic ecologist at the University of North Carolina's Institute of Marine Sciences. In the past, cleanup efforts on lakes and other freshwater bodies could achieve major improvements just by targeting phosphorous pollution, also from fertilizer. But now they routinely face toxic blue-green algae (or cyanobacteria) blooms, fueled by nitrogen pollution. That problem is being exacerbated, Paerl and his co-authors argued in a study last year, by warmer temperatures and increased rainfall associated with climate change. Efforts by water quality managers to protect the water supply may not work in the future, they wrote, because climate change introduces so many new uncertainties about hydrology, stratification, and nutrient dynamics.

Workers navigate their way through an algae bloom in Lake Taihu, China's third largest freshwater lake, in June 2007. LIU JIN/AFP/GETTY IMAGES

These toxic algae blooms have become alarmingly widespread in recent decades, according to Paerl. One such bloom in the western end of Lake Erie forced Toledo, Ohio, to cut off the water supply temporarily to 500,000 residents in 2014. The same thing happened in China's Lake Taihu in 2007, leaving 2.3 million people without water. The threat to human health was not hypothetical. Blue-green algae toxins in the drinking water at a dialysis center in Brazil caused 76 deaths from acute liver failure in a 1996 incident. Those toxins have also caused liver damage in children drinking from China's Three Gorges Reservoir. In the United States, a 2015 study found evidence of blue-green algae

blooms in 62 percent of the 3,100 U.S. counties surveyed and concluded that these blooms were "significantly related to the risk of non-alcoholic liver disease death."

The problem with nitrogen is evident, finally, even on land. Atmospheric nitrogen – from intensive farming and livestock operations, power plants, road traffic, and other sources – now gets deposited everywhere, making soils more fertile. That has the paradoxical effect of reducing plant diversity by displacing native species adapted to nutrient-poor soils. A study last year in *Proceedings of the National Academy of Sciences (PNAS)* examined more than 15,000 forest, woodland, grassland, and shrubland sites across the United States and found that a quarter of them have already exceeded the nitrogen levels associated with species loss. Researchers don't know yet how nitrogen and climate change together will affect plant diversity. But in an experiment in an arid southern California habitat, added nitrogen together with changing rainfall patterns caused a community of native shrubs to shift to non-native grasses.

Farmers are acutely aware of their leading role in this unfolding disaster. In Europe, they have managed to reduce nitrogen use substantially without any decrease in productivity over the past quarter century because of mandatory European Union limits. The United States has so far relied on a voluntary approach, with mixed results. But when the city of Des Moines, Iowa sued upstream farm counties two years ago for the cost of equipment to remove nitrogen runoff from its drinking water supply, many farmers heard alarm bells. (A federal court ultimately dismissed the lawsuit early this year.)

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"I haven't seen a willingness to engage in a conservation program like this in my lifetime," says Nick Goeser, a soil scientist and director of the Soil Health Partnership. The issue resonates with farmers in part because applying nitrogen fertilizer accounts for up to half the cost of running a farm, and they would naturally prefer the expenditure to pay off in increased yield rather than have it wash away down the river. They recognize that nitrogen runoff is contaminating their own drinking water, says Goeser, and they have also noticed the effects of climate change on their crops.

Water flows off a farm in Tennessee following a storm. Scientists project climate-fueled rain events could increase runoff nitrogen in U.S. waterways by 19 percent. TIM MCCABE/USDA

The Soil Health Partnership, which combines agribusiness funding with technical advice from the Environmental Defense Fund and the Nature Conservancy, works to scale up three solutions to the nitrogen problem—use of off-season cover crops to reduce the runoff that inevitably occurs when fields remain bare through the winter, low- or no-till farming, and "advanced nutrient management," or what Goeser describes as "spoon-feeding" nitrogen in the precise amount and time that the plant needs it.

None of that is as simple as it may sound. For instance, use of cover crops "makes an incredible difference, with a 60-80 percent improvement in runoff," says Goeser. It's expensive, however, and could actually decrease corn or soybean yield the following year if the farmer does it wrong. It only starts to improve resilience to extreme weather events like flooding or drought, and thus yield, after three to five years. But in the Midwest, says Goeser, 60 percent of the acreage is operated on a one-year rental basis, meaning farmers have no incentive to invest in the long-term health of the land. Fewer than 5 percent of them plant cover crops.

Advanced nutrient management means switching from applying fertilizer in the fall to the spring, and not all at once in the spring, but in small doses throughout the

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season, with sensors indicating exactly how much nitrogen a specific section of field actually needs. But the 10-foot-high equipment to work with a growing crop is expensive.

Among the long-term solutions being proposed are genetically-engineered cereals that fix nitrogen from the atmosphere and lab-cultured meat.

The combined threat of climate change and nitrogen pollution could soon mandate far more dramatic changes in agriculture. Among the long-term solutions put forward by University of Victoria researchers in a companion piece to the new study in *Science:* Genetically-engineered cereals to fix nitrogen from the atmosphere, and laboratory cultured meat, to reduce the global herd from 1.5 billion head of cattle to a population of just 30,000 that will be used as stem-cell donors. Climate change means that it will be necessary, the co-authors note, to cut agricultural nitrogen use in the Mississippi River Valley not by 32 percent, as the U.S. Environmental Protection Agency now proposes, but by almost double that amount.

The challenge will be far greater in the developing world, particularly Asia. The Stanford-led research team identified three risk factors that make an area more vulnerable to the compounding effects of nitrogen pollution and climate change: heavy nitrogen inputs (mostly for agriculture), a high current rate of precipitation, and a large projected increase in precipitation because of climate change.

East, South, and Southeast Asia face the greatest peril, with India especially vulnerable "because it exhibits all three risk factors across more than two-thirds of its area ... and has one of the fastest-growing populations." People throughout the region "are heavily dependent on surface water supplies," the researchers note. But as climate change multiplies the rate of nitrogen runoff, they may increasingly find their water undrinkable.

Correction, August 8, 2017: *An earlier version of this article incorrectly attributed to Nick Goeser the statement that farmers recognize that nitrogen runoff is poisoning their drinking water. Goeser did not use the word poisoning.*

Richard Conniff is a National Magazine Award-winning writer whose articles have appeared in *The New York Times, Smithsonian, The Atlantic, National Geographic*, and other publications. His latest book is *House of Lost Worlds: Dinosaurs, Dynasties, and the Story of Life on Earth*. He is a frequent contributor to *Yale Environment 360*. MORE →