The Case of the Missing Nitrogen

On-farm practices can reduce nitrogen runoff. But given the nitrogen cycle's complexities, could some also add it to the air?

Brennen Jensen

As Jake Hagedorn concentrates on setting up monitoring equipment to measure nitrogen in the atmosphere, part of his mind focuses on something else: *Don't trip on the corn!* Hagedorn, a doctoral student at the University of Maryland Center for Environmental Science's Appalachian Laboratory, works with lab director Eric Davidson. Once a month for nearly three years now, he leaves the lab's Frostburg facilities for his Eastern Shore field office. In this case, that's *field* in the literal sense.

He's there on a sunny October afternoon, on a farm some two miles west of Marydel in Caroline County, standing before a laptop and other equipment set up on a folding table amid rows of corn stover. "They're like knives," he said of the long rows of desiccated stalks at his feet. He added that he's also been out here at the height of the growing season when the corn towers over his head, which he equated to working in a shadowy maze. Such are the challenges of fieldwork.

Hagedorn employs a flux chamber measurement system, which uses a series of metal rings embedded in the soil, each about a foot in diameter. Moving from one ring to another, he temporarily connects a chamber—roughly the size and shape of a large inverted mixing bowl—to each ring. Hoses connect each chamber to gas-measuring equipment on the table. While he practices agricultural soil science and will earn a degree in environmental science, in his fieldwork he applies a rule borrowed from the medical profession: First, do no harm.

Jake Hagedorn, a doctoral student at the University of Maryland Center for Environmental Science's Appalachian Laboratory, employs a system to measure nitrogen gases that may be released as an unintended consequence of denitrifying practices. *Photo, Brennen Jensen*

He is testing the effectiveness of a potential best management practice for farming that could decrease the amount of nitrogen fertilizer leaching from fields and ending up in the Chesapeake Bay, where it can cause harmful algal blooms.

As is typical of Eastern Shore farmland, the fields where Hagedorn works are flanked by drainage ditches, some of which have flow-control devices that can be manually manipulated to reduce the outflow and keep more water in the fields they serve. That enables the farmer to control how much water stays on the field, and for how long. As a potential best management practice, the theory is that this approach will alter soil chemistry dynamics and reduce water pollution from the farm field.

But there's a potential catch: The process might also create nitrous oxide (N_2O), a greenhouse gas that's 300 times more potent than carbon dioxide (CO_2). If conditions get too wet and become anaerobic—a condition in which no oxygen is present—bacteria can start to produce methane (CH_4), another greenhouse gas.

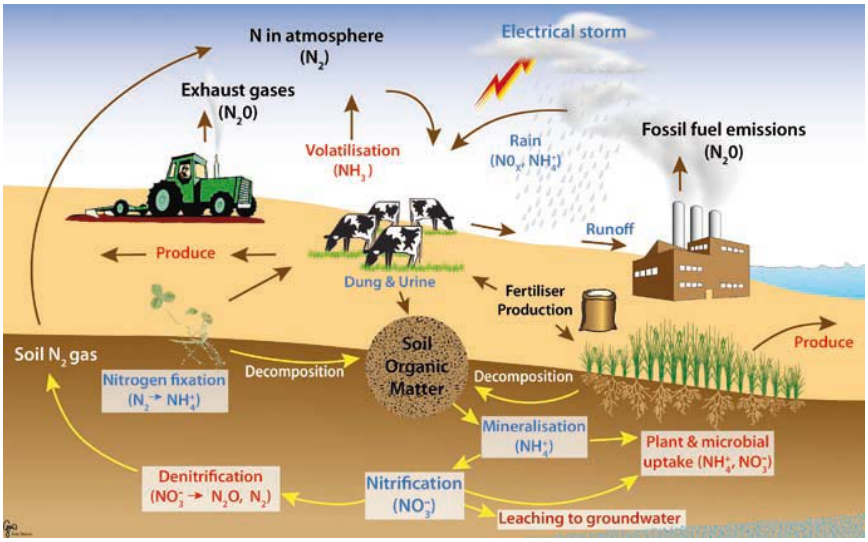
To test the method and its potential downside, Hagedorn set up a treatment field, installing flow-control devices on about half of the 40 acres he's investigating; the other half of his acreage was left untouched as a control area.

"If we get too much nitrous oxide coming out, are we just trading one form of pollution for another?" Hagedorn wondered. "That's the question we're investigating for this best management practice."

A Complex Cycle

Phosphorus and nitrogen are the two most problematic fertilizers when it comes to polluting the Bay. Of the two, phosphorous is easier to track and measure after farmers apply it to crops and it cycles through the environment, because of what scientists call its "sticky" characteristics. After farmers apply phosphorus to fields, the crop absorbs a certain amount at harvest time. The soil holds on to some, plant residue retains some, and some enters the watershed. Because of its stickiness, scientists can balance it—that is, they can determine quantitatively, with a certain degree of confidence, where each pound of phosphorus ends up after application.

Nitrogen, on the other hand, seems conditioned to "run," assuming gaseous forms. In a process called denitrification, naturally occurring soil bacteria convert nitrogen fertilizer into atmospheric nitrogen (N_2), the harmless gas that makes up more than 78 percent of the air we breathe. But certain forms of denitrification can also create the potent nitrous oxide (N_2O).



The nitrogen cycle illustrates the complexity of measuring the element in its gaseous form. Farmers are putting lots of practices on the ground, but scientists are trying to figure out if denitrification unintentionally releases nitrogen into the air. The above graphic shows the principle components of the terrestrial nitrogen cycle. *Graphic, Louis A. Schipper and Max Oulton, The University of Waikato*

"We don't know where all the nitrogen goes," said Tom Fisher, professor emeritus at the University of Maryland's Horn Point Laboratory. He said that accounting for the missing nitrogen is one of the pivotal challenges in the emerging field of nitrogen biochemistry.

"There's a bunch of it somewhere," Fisher explained. "So the issue is, [is] it being stored in the soil or groundwater, or is it being converted into nitrogen gas and leaving into the atmosphere? There's lots of denitrification going on, but it's difficult to measure. One of the big problems is that nitrogen is just so prevalent, and trying to measure some small flux into this big pool of nitrogen in the air is analytically difficult."

In other words, it's easier to detect and measure anomalies in the air, such as trace amounts of nitrous oxide, than to measure minute changes in the amount of nitrogen, which is already abundant. (Fisher noted that he and some students at Horn Point Laboratory have developed a promising technique to measure nitrogen denitrification that detects changes in the ratio of argon gas to atmospheric nitrogen.)

What *is* understood is that the soil bacteria responsible for denitrification prefer anoxic environments, where there is very little dissolved oxygen—conditions found commonly in wetlands.

And that brings us back to Hagedorn's cornfield and the notion of manually slowing the water outflow and creating wetter soil conditions. Researchers also are concerned that artificially created soil conditions might facilitate chemical reactions that could increase the amount of phosphorus entering the watershed. That could happen if yet another type of bacteria converts a stable form of iron commonly found in soil to a water-soluble version, chemically freeing up excess phosphorus to enter groundwater as well.

"Cautiously Optimistic"

It all goes back to the "do no harm" concept—but so far, so good. "We're cautiously optimistic, as my measurements have not detected a significant difference in nitrous oxide production between the treatment and control fields," Hagedorn said. Methane production has not been an issue either.

And the situation in the ditches appears positive so far as well. "Our data shows there is about three times less nitrogen being exported from the treatment ditches than the control ditches," said Anne Gustafson, a Horn Point senior faculty research assistant involved with the water analysis. "This is based on two years of data and is still being monitored and analyzed." Phosphorus leaching did increase some in the treatment field, but by a much smaller amount when compared to the sizable reductions in nitrogen. Still, the researchers say, it only underscores the complexity of soil chemistry and the need for thorough monitoring.

The chamber method records only a snapshot of gas emissions in the area directly under the chamber, and emissions can vary based on temperature, humidity, and other atmospheric conditions. To make up for some of the shortcomings of the chamber system's nitrous oxide measurements, Hagedorn shares his field with an automated system for measuring gas emissions. It features four apparatus-festooned towers, each about four feet tall, that collect data on nitrous oxide and methane emissions around the clock over a wide area.

Davidson—a PhD in forestry who focuses on biochemistry and greenhouse gas exchanges among groundwater, soil, plants, and the atmosphere—said the tower measurements aren't as sensitive as the chambers. But using both enables researchers to go both a mile wide and a few inches deep, so to speak. And so far, the high-tech towers back up what Hagedorn has discovered manually.

"We are probably stimulating nitrous oxide a little bit, but not enough for us to be able to conclude a statistically significant difference from the control site," Davidson said. "And so if that result holds, that's good news in terms of this best practice being something that can really be used to reduce nitrate runoff."

Header photo: Jake Hagedorn, a doctoral student at the University of Maryland Center for Environmental Science's Appalachian Laboratory, records nitrogen data on an Eastern Shore farm. Photo, Brennen Jensen

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