To predict environmental changes, researchers create a new generation of wireless sensor networks

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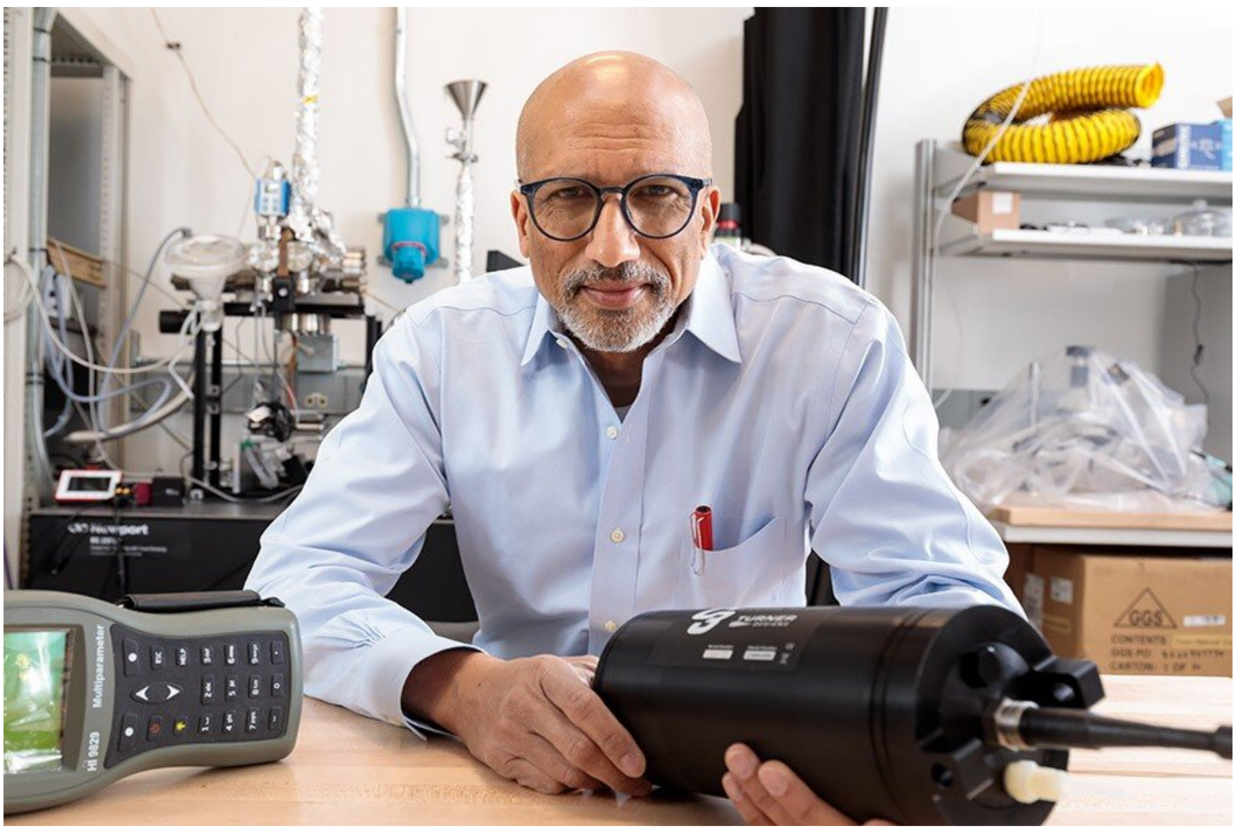

Prof. Supratik Guha has pioneered wireless sensor networks, systems able to monitor soil and water quality in real-time, vastly improving environmental data for climate modeling and precision agriculture. Large sensor platforms, seen above, are used to measure water parameters such as chlorophyll and tryptophan. Credit: John Zich

The "internet of things," a growing web of interconnected devices—constituting everything from smart bulbs to warehouse robots—is posited as a central pillar of the "fourth industrial revolution" because of how drastically it improves connectivity and information sharing.

Now imagine that web expanding beyond buildings and into the landscape, forming a sensory network that monitors the air, soil, and water for pollution and nutrient content. Such a network is the goal of Supratik Guha, professor at the University of Chicago's Pritzker School of Molecular Engineering (PME) and senior advisor at Argonne National Laboratory.

He and his team are developing "wireless sensor networks"—sensor arrays that surveil acre-wide swathes of land and water to track pollution, moisture levels, and chemical composition. These systems, Guha believes, will unlock sorely needed data on the planet's rapidly shifting composition.

"These sensor networks will provide real-time, high-density data that are essential to creating an accurate picture of an ecosystem," said Guha. "We want to see how rivers are being polluted, how much fertilizer is washing out of the soil. With better data, terrestrial ecologists can develop better nitrogen and carbon dioxide cycling models; farmers can use exactly the right amount of water at exactly the right time."

Collectors of small things

In agriculture, small data points can have far-reaching implications. Volumetric water content—how much water is absorbed into a particular patch of dirt—dictates whether a farmer irrigates his field today or puts it off. Too little water and the plants may wither. Too much water exacerbates soil erosion, wastes an increasingly rare resource, and contaminates the downstream supply.

The same can be said for terrestrial ecology—data is king. But quality data on short-term environmental changes have historically been hard to come by until recently.

Capitalizing on the advent of less expensive sensors and low-powered wireless systems such as Sigfox, Prof. Guha and his team have created three separate environmental sensor networks under the project name Thoreau (after the famous naturalist Henry David Thoreau). One such network monitors water quality in several Indian rivers, another records ground moisture around the University of Chicago campus, while a third collects soil information year-round at a pilot farm near Fermi National Laboratory in Batavia, Illinois.

Fourth-year Ph.D. student Gregory Grant, who works on the project, explains its broader potential.

"By deploying sensors unobtrusively across a field or, say, a national forest or a nature preserve, we can monitor water quality or soil temperature," said Grant. "In a place like California, that's a powerful tool to monitor for wildfire or help agricultural management. We can make informed decisions about hazards, water usage, fertilizer runoff, pollution—there's so much we learn."

The network’s communication nodes (above) are encapsulated in clear, waterproof plastic and buried a foot and a half below the surface. Credit: Guha Lab

The data natural

Sensor technology evolves rapidly, and the particular components used in each of the Thoreau networks has varied over time. The Fermi farm network (Thoreau 2.0) uses a relatively inexpensive soil sensor connected to a plastic-encased circuit board. These "nodes" look something akin to a small, screenless smartphone with a pronged antenna extending from one end.

Each of the farm's 23 nodes are buried a foot and a half beneath the surface where they detect volumetric water content, temperature, and soil electrical conductivity. Four AA lithium-ion batteries power the nodes, giving them an operational lifespan of roughly four and a half years.

Key to the sensors' longevity is their use of low-power wide-area network (LPWAN) hardware, a technology that transmits small amounts of data at lower frequencies, sometimes referred to as "zero-G" networks.

Once buried, the nodes collect information every thirty minutes, relaying it to a 30-foot-tall solar-powered base station situated in the middle of the field, which in turn transmits the information to Guha's lab. Once processed, the data is displayed publicly on the project webpage.

The network has been in operation since 2019 and has required almost no maintenance, demonstrating that it can function for years without interfering with day-to-day farm operations.

Research on the ecological scale

Professor Guha's first environmental sensor network to monitor river pollution was developed in 2017 in India. Since then, he and his team have joined a global collaborative effort to apply state-of-the-art technology toward environmental sustainability and advanced agriculture.

The NSF and USDA support the pilot network as part of the Artificial Intelligence for Future Agricultural Resilience, Management, and Sustainability (AIFARMS) Institute. AIFARMS is a multi-institution body advancing foundational AI to address important challenges facing world agriculture.

That collaborative spirit, Guha says, is essential to tackling such massive issues and one reason why he was drawn to UChicago.

"A big reason I came to the University of Chicago was to explore different pursuits and work with this network of experts," said Guha. "In fact, my water project began out of a collaboration with Anup Malani from the UChicago Law School, and then grew further via interactions with The Energy Policy Institute (EPIC) and The University of Chicago's Delhi office. Problems are multifaceted. There are socio-economic considerations, political considerations, regulatory considerations, business considerations—for today's complicated environmental problems, you need that network to make a real impact."

Looking to the future, Guha aims to bring down the cost of his sensor units even further while simplifying the system as a whole.

"Sensor networks have come a long way, in that you can put together a system by integrating easily available and standardized components," said Guha. "The future research in this area will focus on making the networks affordable so that they can be deployed at scale, globally. We are also working to develop new sensors that can easily measure many parameters that we cannot reliably measure today: such as nitrate content in soil and microbial content in water and soil."

Provided by University of Chicago

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