

# Powerful sensors on planes detect crop nitrogen with high accuracy

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Hyperspectral sensors affixed to small aircraft can accurately detect nitrogen status of crops. Credit: University of Illinois at Urbana-Champaign

Synthetic nitrogen fertilizers transformed agriculture as we know it during the Green Revolution, catapulting crop yields and food security to new heights. Yet, despite improvements in crop nitrogen use efficiency, fears of underperformance spur fertilizer overapplication to this day. Excess nitrogen then ends up in waterways, including groundwater, and in the atmosphere in the form of potent greenhouse gasses.

Predicting the amount of [nitrogen](#) needed by a particular crop in a particular year is tricky. The first step is understanding crop nitrogen status in real time, but it's neither realistic nor scalable to measure leaf nitrogen by hand throughout the course of a season.

In a first-of-its-kind study, a University of Illinois research team put hyperspectral sensors on planes to quickly and accurately detect nitrogen status and photosynthetic capacity in corn.

"Field nitrogen measurements are very time- and labor-consuming, but the airplane hyperspectral sensing technique allows us to scan the fields very fast, at a few seconds per acre. It also provides much higher spectral and spatial resolution than similar studies using [satellite imagery](#)," says Sheng Wang, research assistant professor in the Agroecosystem Sustainability Center (ASC) and the Department of Natural Resources and Environmental Sciences (NRES) at U of I. Wang is lead author on the study.

"Our approach fills a gap between field measurements and satellites and provides a cost-effective and highly accurate approach to crop nitrogen management in sustainable precision agriculture," he adds.

The plane, fitted with a top-of-the-line sensor capable of detecting wavelengths in the visible and near infrared spectrum (400-2400 nanometers), flew over an experimental field in Illinois three times during the 2019 growing season. The researchers also took in-field leaf and canopy measurements as ground-truth data for comparison with sensor data.

The flights detected leaf and canopy nitrogen characteristics, including several related to photosynthetic capacity and grain yield, with up to 85% accuracy.

"That's close to ground-truth quality," says Kaiyu Guan, co-author on the study, founding director of the ASC, and associate professor in NRES.

"We can even rely on the airborne hyperspectral sensors to replace ground-truth collection without sacrificing much accuracy. Meanwhile, airborne sensors allow us to cover much larger areas at low cost."

Remote sensing picks up energy reflected from surfaces on the ground. The chemical composition of leaves, including their nitrogen and chlorophyll content, subtly changes how much energy is reflected. Hyperspectral sensors detect differences of just 3 to 5 nanometers across their entire range, a sensitivity unmatched by other remote sensing technologies.

"Other airborne remote sensing technologies pick up the visible spectrum and possibly near-infrared, just four spectral bands. That's not even close to what we can do with this hyperspectral sensor. It's really powerful," Guan says.

The researchers see a use for their findings in the popular Maximum Return To Nitrogen (MRTN) corn nitrogen rate calculator.

Wang explains, "Under our approach, we can detect the nitrogen status of the crop and make some real-time adjustments for the agricultural stakeholders. MRTN provides recommended nitrogen fertilization rates based on the economic tradeoff between soil nitrogen fertilizer rates and end-of-season yield. Our [remote-sensing](#) approach can feed plant nutrient status into the MRTN system, enabling real-time crop nitrogen management. It can potentially shift the current recommendations based on pre-growing season, soil-centric fertilization to a diagnosis based on real-time plant nutrition, improving agroecosystem nitrogen use efficiency."

Importantly, the research team worked out the best mathematical

algorithm to detect nitrogen reflectance data from the hyperspectral sensor. They expect it will be put to use as newer technologies come on board.

"NASA is planning a new satellite hyperspectral mission, as are other commercial satellite companies. Our study can potentially provide the algorithm for those missions because we already demonstrated its accuracy in the aircraft hyperspectral data," Wang says.

Guan says bringing this technology to satellites is the end goal, enabling a view of every field's nitrogen status early in the growing season. The advancement will allow farmers to make more informed decisions about nitrogen side-dressing.

Ultimately, of course, the goal is to improve the environmental sustainability of nitrogen fertilizers in agronomic systems. And Guan says precision is the way to get there.

"Essentially, you can't manage what you can't measure. That is why we put so much effort into this technology."

The article is published in the *International Journal of Applied Earth Observation and Geoinformation*.

**More information:** Sheng Wang et al, Airborne hyperspectral imaging of nitrogen deficiency on crop traits and yield of maize by machine learning and radiative transfer modeling, *International Journal of Applied Earth Observation and Geoinformation* (2021). [DOI: 10.1016/j.jag.2021.102617](https://doi.org/10.1016/j.jag.2021.102617)

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