Flying high technology accurately detects crop nitrogen

SYNTHETIC nitrogen fertilisers 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 fertiliser overapplication to this day. Excess nitrogen then ends up in waterways, including groundwater, and in the atmosphere in the form of potent greenhouse gases.

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 (U of I) 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 labour-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," said 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 said.

Hyperspectral sensors flown in small aircraft can provide data from which the nitrogen status of crops can be assessed. (CREDIT: UIUC image)

Flying high but close to 'ground-truth' accuracy

The plane, fitted with a top-of-the-line sensor capable of detecting wavelengths in the visible and near infrared spectrum (400–2400 nanometres), 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," said Kaiyu Guan, co-author on the study, founding director of the ASC, and

Taking the sensor in the air gives you a vantage point to very quickly search soil characteristics and plant species over larger area.

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 nanometres across their entire range, a sensitivity unmatched by other remote sensing technologies.

Earlier systems just four bands

"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 said.

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 said.

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.

Environmental sustainability of N

Ultimately, of course, the goal is to improve the environmental sustainability of nitrogen fertilisers 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," Guan said.

The article, "Airborne hyperspectral imaging of nitrogen deficiency on crop traits and yield of maize by machine learning and radiative transfer modeling," is published in the International Journal of Applied Earth Observation and Geoinformation.

For more information: *www.aces.illinois.edu* ■

WHAT IS AIRBORNE HYPERSPECTRAL IMAGING?

Any material that is detectable either directly or indirectly based on its spectral features, can be mapped with an airborne hyperspectral camera. The point of airborne hyperspectral imaging is to create a material map of the study area, land or water surface.

Airborne sensors currently in use provide:

- Detailed geometric models – (LiDAR);
- Information on the texture and structure of target objects – Synthetic aperture radar (SAR); and,
- Spectral information of the Earth's surface for identifying land cover types – Multispectral imaging (MS).

How does hyperspectral imaging differ?

Multispectral imagers typically have 3-5 broad bands with gaps in between, depending on which applications the multispectral imager is built for. The digital camera found on your smartphone, is a multispectral imager with 3 spectral bands. Thus, multispectral can mean almost anything from a general consumer camera to an application specific imager.

By definition, hyperspectral imaging collects hundreds of contiguous, narrow spectral bands. This means that there are no "gaps" between the bands. Hyperspectral means far more, more narrow bands than multispectral imaging.

Resulting differences for a user are threefold. With hyperspectral imager, you can differentiate material (minerals, plants etc) of much smaller spectral difference, thanks to much higher spectral fidelity.

Identify plant – and plant health

With a multispectral imager you can – for example – tell if the area has vegetation or not. With a hyperspectral imager, you can tell which species the vegetation consists of, and moreover, if those plants are suffering a stress, and at best, what is the cause of the stress.

Multispectral imaging may be enough to tell asphalt apart from gravel or concrete, but in order to tell how old the asphalt is and what is its material composition, you need more and narrower bands provided by the hyperspectral imager.

There's gold in them there hills!

Only hyperspectral imagery can differentiate minerals that are important for geologists, but which exhibit such minute spectral differences that multispectral imagery is unable to tell them apart. There are many such minerals!

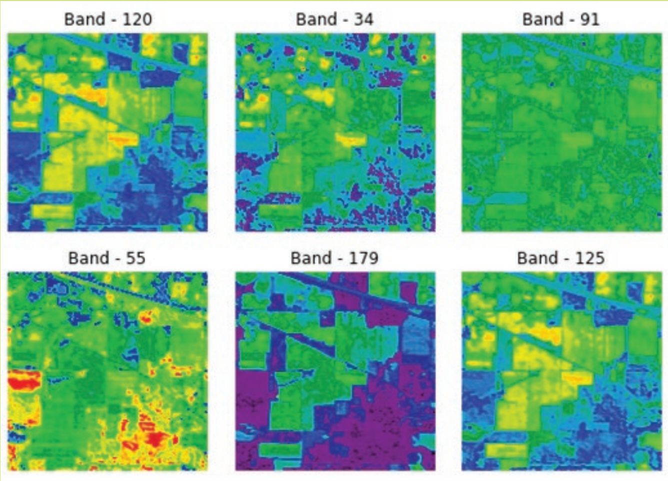
Information for any application

Multispectral imagery is designed for a particular application, whereas hyperspectral imagery is application agnostic; it collects all the spectral information from the target and so doing serves all possible applications, only limited by the skill of the analyst.

This means that you can come back to the collected data and turn it into an application – or several applications – you were not tasked with originally. As long as the data is collected well, it can be turned into dozens of different applications. If organisation is collecting hyperspectral data for a client, it is wise to price full rights reflecting the future potential of the dataset!

Drawn from: The Top 10 Questions about Airborne Hyperspectral Imaging by Specim, a Konica Minolta company.

For more information: *https://www.specim.fi*



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