Science Societies

Inexpensive color sensor quantifies soil total iron

By DJ McCauley

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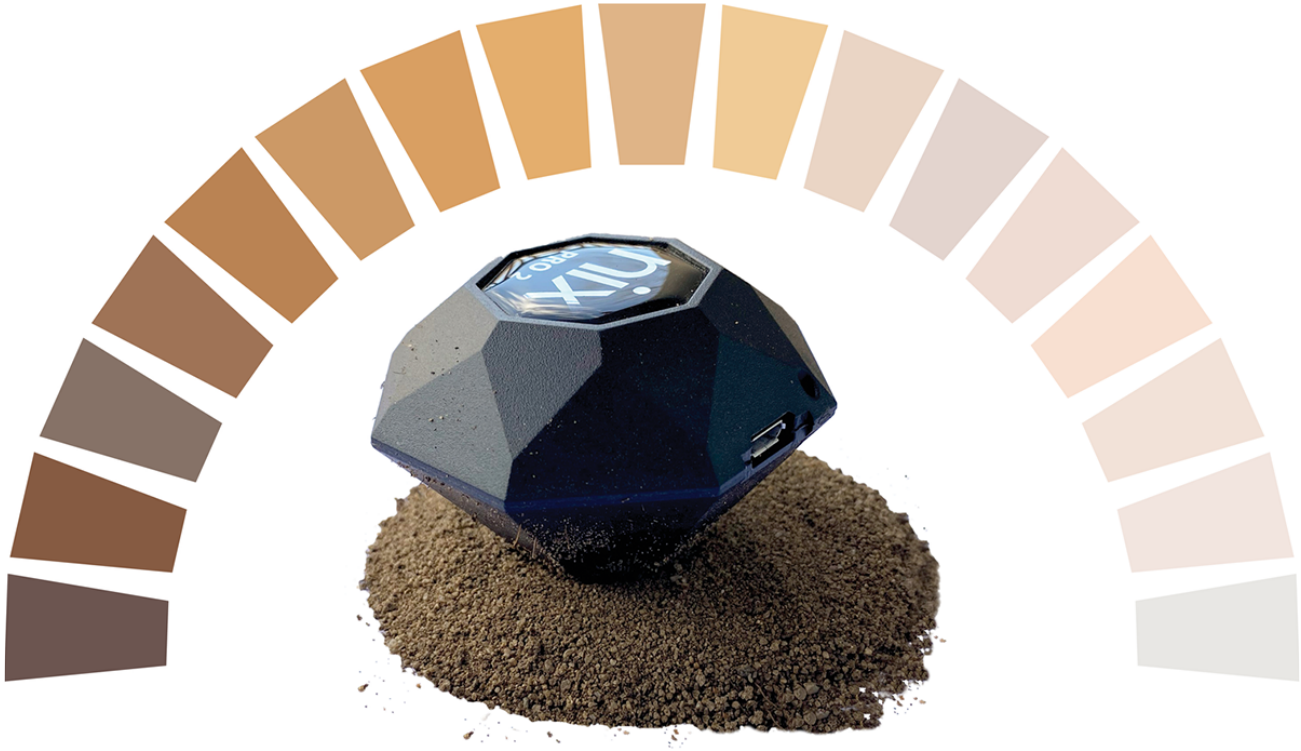

Photo by Gaurav Jha, UC-Davis.

The Nix Pro is an affordable handheld tool for getting exact color matches that you'd most commonly see in paint stores.

Instead, researchers took it to the field to analyze soil color and see if it can accurately estimate iron content.

In a new study in *Agricultural & Environmental Letters*, the research team released models for using the Nix Pro on New Mexico soils, showing that it can efficiently and accurately quantify soil iron.

There you are in the field again, soil clump in your hand, matching it with swatches in a thick book of Munsell charts.

Photo courtesy of Flickr/U.S. Department of Energy.

It's a pretty foolproof way to classify soil color, given some practice. And the National Resource Conservation Service sites the **Munsell System** as a means of comparing soils anywhere in the world using the color, lightness and darkness, and color intensity of the soil. But if you wanted to dig deeper to see mineral or organic carbon content, you'd have to send soils off to the lab for often

expensive, time-consuming analysis.

Imagine if you could measure soil color, right there in the field, to quantify important soil properties, all without sending soil samples to the lab?

That's exactly what a team spanning four universities in as many states set out to do using the relationship between iron content and soil color.

In a new *Agricultural & Environmental Letters* (AEL) study (**https://doi.org/10.1002/ael2.20050**), researchers used a handheld color sensor to quantify soil iron in the field. The study makes use of the small, inexpensive **Nix Pro** to create models of soil total iron content. It's a first step for a handy tool that could make life easier for scientists seeking quantifiable iron content measures to make management decisions in the field.

No Paint Here

It used to be that the best scientific conversations happened over beverages in bars, but in the age of COVID-19, those conversations shifted to coffee talks via Zoom.

"I was talking with Debjani [Sihi] and [Biswanath] Dari over coffee about the Nix Pro," Gaurav Jha, first author on the AEL study and postdoctoral researcher at the University of California–Davis, says. He first heard about the tool from David Weindorf, a researcher at Central Michigan University.

The Nix Pro—a palm-sized, diamond-shaped light-emitting spectrometer—is commonly used by folks in paint stores, color consultants, print technicians, and graphic designers. You hold the LED-emitting side up to a paint swatch, and the Nix Pro measures the reflectance, giving you an exact color composition in three different color spaces. And it retails for just US$349 on the **Nix Pro site**—a far cry cheaper than

most benchtop spectrometers.

“I work on redox processes, and I immediately thought it was important for that,” says Sihi, corresponding author and assistant professor in the Department of Environmental Sciences at Emory University.

The Nix Pro soil sensor is a handheld device for sensing total iron content in soil without analyzing the samples in the lab. Photo by Gaurav Jha, UC-Davis.

Why redox? Redox reactions in the soil typically rely on electron acceptors like oxygen, manganese, and iron. Shades of red in soils come from the unreduced form of iron, Fe^{3+}, which, under saturated soil conditions, is reduced to Fe^{2+}. When this happens, the soil color often changes from a shade of red to a lighter grey color. Even without color shifts, Sihi and her coauthors suspected that using the Nix Pro to take reflectance information could give them insights into total iron content in soil samples.

“Iron, as a micronutrient, is an incredibly important for crop production,” Sihi explains. “It’s one of the fundamental mineral species that dictates many other soil functions, like carbon storage, greenhouse gas emissions, and nitrogen and phosphorus cycling.”

As part of his doctoral research work with April Ulery and Kevin Lombard, Jha had collected a small library of soil samples from the Animas Watershed in New Mexico. The best part? He’d already analyzed the samples for total iron content in the lab, creating a dataset the team could use to both calibrate and validate a model made by the Nix Pro.

Layers on Printer Paper

Collecting color data with the Nix Pro is simple. If you were a graphic designer in need of a perfect color match, you'd just set the Nix Pro up against the surface of whatever object you're matching, click a tab on your phone, and the little sensor sends information about the color via Bluetooth.

But if you're testing soil samples, you'd need some paper. Jha returned to his soil samples from New Mexico, choosing a selection to calibrate the model. He spread the soil 2 or 3 cm deep on a few sheets of white printer paper. Then, he set the Nix Pro on top and collected color data in three different color spaces: **CMYK** (cyan, magenta, yellow, and black), **CIEL*a*b** (which includes lightness and darkness), and RGB (red, green, blue). You can quickly organize the data collected from samples into folders, which you can export from the app as an Excel document. Pretty slick!

Then Harpreet Kaur, a Ph.D. candidate at New Mexico State University (NMSU), came in. She helped calibrate and validate models relating the collected data from the Nix Pro with the laboratory-gathered total iron content. The team created a different model for each color space, using the percentage of total iron content in the soil as a dependent variable. They then compared the agreement between the soil iron estimates from these models with the data generated by the ICP tests from Ulery's lab at NMSU. They found that all three models were significant (= .05) in predicting soil Fe content, but the CMYK color space was the most spot-on.

Finally, they validated the CMYK model by using it to estimate total iron content in soil samples from an adjacent field. The model, when compared to the lab-generated iron content data, predicted iron content with an R-squared value of 0.92. That is, the model is about 90% accurate in predicting total iron content in these particular soils when using a calibrated model.

Debjani Sihi (Emory University), Gaurav Jha (University of California–Davis), and Biswanath Dari (North Carolina A&T State University) use Nix Pro in the field. Photo by Aneesh Chandel.

"Ordinarily, if you wanted to know soil iron content, it's a really costly, long process to analyze samples in the lab," Sihi says. "But the Nix Pro is a really handy, inexpensive tool, and I was quite pleased to see the results of our study."

A Handy, Inexpensive, Versatile Tool

The Nix Pro, with proper validation for new soil types, could be a great means of understanding total soil iron within minutes instead of months. The model created for New Mexico soils is a start, but other scientists around the world need to test the Nix Pro in new soils, including those with high soil organic matter and under a range of soil total iron content.

"We're really hoping to create a package of properties the Nix Pro can measure," Jha says. "Currently, I'm working with my lab members Mallika Nocco and Dawson Diaz to use the sensor to measure lycopene content in tomatoes under deficit irrigation in California."

Among other projects, the researchers hope to find correlations between shades of soil color and the species of iron in the soil, whether it's the bioavailable Fe^{2+} or the unavailable Fe^{3+}. The researchers are also interested in investigating other minerals that influence soil color. The team is also planning to develop the model for agronomic properties that depend on color or spectral reflectance.

"It's so exciting because this tool is really affordable, it's portable, and it could make it easier for *anyone* to understand what's going on in their soil," Jha says.

Though the soil iron models created from New Mexico soil samples are a great first step, there's much more work to do with the sensor. In fact, Jha mentioned that they'd like to find a way to use the sensor in conjunction with the Munsell System. In the meantime, Dari, Sihi, Jha, and other coauthors on the project are seeking further funding to research Nix Pro's uses. Keep your eyes peeled.

Dig deeper

Read the original article, "Rapid and Inexpensive Assessment of Soil Total Iron Using Nix Pro Color Sensor," in *Agricultural & Environmental Letters* here: **https://doi.org/10.1002/ael2.20050**.

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