Harnessing light reflections from leaves to learn more about biodiversity and the characteristics of plants

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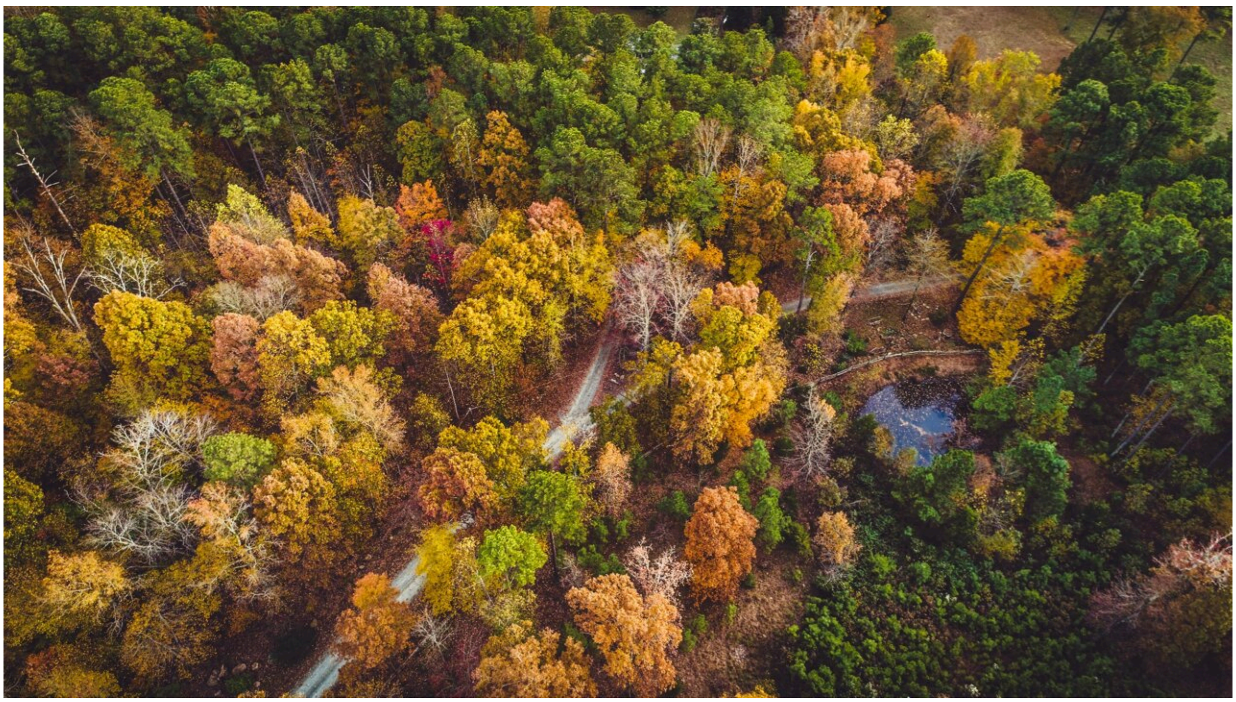

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The folded leaf of an oak tree, faded yellow, dotted with dark spots. We pick up on the information contained in leaves almost subconsciously when strolling through the forest. But the researchers at UZH's Remote Sensing Laboratories are taking this ability to the next level.

Using a spectrometer, they measure the light reflected by leaves, which gives them insight into the chemical and structural properties of plants—even from outer space. "The spectrum is like a fingerprint unique to each plant," explains Meredith Schuman, professor of spatial genetics in the Department of Geography.

Monitoring plant life using satellites, airplanes and drones is known as remote sensing, and it could become an important tool to counteract the biodiversity crisis. Remote sensing makes it possible to monitor the health and species composition of ecosystems, almost in real time. This could help governments identify areas that require protection at an early stage and provide direct feedback on conservation measures.

Calibration using field measurements

"We're in the process of finding out which aspects of plant biodiversity can be measured with remote sensing," explains Anna Schweiger, a researcher at the UZH Remote Sensing Lab. Schweiger and Schuman need reference data from the field to ensure that they are interpreting the spectral data correctly. Computer models help them pinpoint concordance between spectral and field data and provide input on how to read the spectral information that they have obtained. "Pigments like green chlorophyll are the easiest to identify, since they absorb specific wavelengths," explains Schuman.

Spectrometry isn't just confined to visible light, however: it also includes additional parts of the electromagnetic spectrum such as infrared light. Leaves reflect infrared rays at the edge of the visible light spectrum, the near-infrared spectrum, particularly strongly. "We call this transitional area the 'red edge,'" says Schuman. "This reflection pattern provides insight into chlorophyll content and the waxy layer on the surface of the leaves."

Her group is working on using spectral data to obtain information about the genetic profiles of plants, which would allow researchers to study genetic differences within species and to draw conclusions about genetic diversity. A long-term study of beech trees in the Lägern mountain range led by doctoral student Ewa Czyz showed that spectral data points involving water content, phenols, pigments and wax composition are suitable indicators for obtaining information about the genetic structure of flora.

One of the team's goals is to improve their understanding of these relationships. Genetic variation within a species is particularly important for biodiversity, since a large gene pool gives plants more leeway to react to negative environmental factors such as pests or droughts. "If we lose genetic diversity and species diversity, ecosystems lose their ability to absorb external shocks," explains Schweiger.

Researchers in Schuman's unit—chiefly the 4D Forests group led by Felix Morsdorf—combine spectroscopy with laser scanning, which involves measuring a laser beam reflected back by the soil or plants and recording the topography and height of the vegetation. "The 3D models that we calculate from this provide insight into the macrostructure—the structure of the plants visible to the eye—as well as how this influences spectral data," says Schuman. The combination of laser scanning and spectroscopy is considered highly promising, as these data allows researchers to calculate the biomass and the amount of stored carbon, for example.

Diverse plant communities

The two researchers aren't just looking for direct connections between spectrums and plant characteristics; they are also comparing the spectrums with one another. "Plants with similar characteristics and related species display similar spectrums," explains Schweiger.

She has developed a spectral diversity index that shows diversity both within and between plant communities (alpha and beta diversity, respectively). The resolution of the spectral data is critical in terms of assessing diversity of this kind. "We need extremely high resolution in order to identify individual plants, which is required for estimating the alpha diversity. This means that there should only be one plant per pixel," says Schweiger.

Satellite-based image spectrometers—similar to what NASA and the ESA are currently developing—make records of the Earth's surface in 30 x 30–meter chunks. "What's easy to compare with these large pixels that capture a lot of individual specimens are the differences in species composition between plant communities: in other words, the beta diversity," explains Schweiger.

From leaf to soil

The idea is that in the future, leaves should even be able to provide information about soil quality, since plants are a main contributor to soil characteristics. "Dead vegetation, for example, influences soil processes and microbial activities," says Schweiger. She worked on a study that used remote sensing data to investigate which properties of plants impact the enzyme activity, microorganism diversity, organic carbon content and nitrogen content of soil.

The results of the study indicate that the relationships between vegetation and soil processes vary depending on the ecosystem. "First we need to understand how productive and species-rich a particular ecosystem is compared to other ecosystems before we can start making statements about the properties of the soil," adds Schweiger. It is this complexity that makes it a challenge to analyze remote sensing data—in addition to the vast quantities of information that remote sensing generates. The data points depend on when they were recorded and the environmental conditions at that moment—spectrums that change within a matter of seconds.

Schuman would even like to extend remote sensing to certain chemical compounds that are emitted by cells and organisms to communicate with one another. Insects can detect molecules from food plants several kilometers away and use these scents to navigate toward their source of sustenance. "For our technology, it's still difficult to record this kind of information remotely," says Schuman. A geneticist by training, Schuman is particularly intrigued by the idea of using remote sensing to record molecules of this kind, since they have a direct tie to genes. "Genes contain the assembly instructions for proteins, which in turn put these chemical compounds together," she explains.

The only one of its kind

Schuman and Schweiger found their way to their current research field in part thanks to conversations with UZH president and remote sensing expert Michael Schaepman. For decades now, the University of Zurich has been on the bleeding edge of developing remote sensing technology, and the university recognized the significance of remote sensing for biodiversity early on. UZH has been commissioned by NASA and the ESA to conduct test flights with AVIRIS-NG, the latest device in imaging spectrometry. "This measuring instrument is the only one of its kind in the world," says Schweiger.

It wasn't always the case that the two researchers' work forced them to gaze upon the heavens. They both spent a lot of time evaluating small patches of land in the field, particularly early on in their careers in ecology. "I always wondered if my findings also held true for nearby habitats," says Schweiger. Remote sensing methods allow for field measurements to be extrapolated to larger areas and for larger areas to be monitored more easily. Remote sensing was also the missing piece for

Schuman. "This method poses new questions and has changed the way we research ecosystems," she says. It remains to be seen what mysteries leaves will reveal about the Earth's ecosystems in the future.

Provided by University of Zurich

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