Researchers develop new way to measure crop yields from space

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As Earth's population grows toward a projected 9 billion by 2050 and climate change puts growing pressure on the world's agriculture, researchers are turning to technology to help safeguard the global food supply.

A research team, led by Kaiyu Guan, a postdoctoral fellow in Earth system science at Stanford's School of Earth, Energy, & Environmental Sciences, has developed a method to estimate crop yields using satellites that can measure solar-induced fluorescence, a light emitted by growing plants. The team published its results in the journal *Global Change Biology*.

Scientists have used satellites to collect agricultural data since 1972, when the National Aeronautics and Space Administration (NASA) pioneered the practice of using the color – or "greenness" – of reflected sunlight to map plant cover over the entire globe.

"This was an amazing breakthrough that fundamentally changed the way we view our planet," said Joe Berry, professor of global ecology at the Carnegie Institution for Science and a co-author of the study. "However, these vegetation maps are not ideal predictors of crop productivity. What we need to know is growth rate rather than greenness."

The growth rate can tell researchers what size yield to expect from crops by the end of the growing season. The higher the growth rate of a soybean plant or stalk of corn, for instance, the greater the harvest from a mature plant.

"What we need to measure is flux – the carbon dioxide that is exchanged between plants and the atmosphere – to understand photosynthesis and plant growth," Guan said. "How do you use color to infer flux? That's a big gap."

Solar-induced fluorescence

Recently, researchers at NASA and several European institutes discovered how to measure this flux, called solar-induced fluorescence, from satellites that were originally designed for measuring ozone and other gases in the atmosphere.

A plant uses most of the energy it absorbs from the sun to grow via photosynthesis, and dissipates unused energy as heat. It also passively releases between 1 and 2 percent of the original solar energy absorbed by the plant back into the atmosphere as fluorescent light. Guan's team worked out how to distinguish the tiny flow of specific fluorescence from the abundance of reflected sunlight that also arrives at the satellite.

"I think of it like crumbs falling to the ground as people are eating. It's a very small trail," said David Lobell, associate professor of Earth system science at Stanford's School of Earth, Energy, & Environmental Science and a co-author of the study. "This glow that plants have seems to be very proportional to how fast they're growing. So the more they're growing, the more photosynthesis they're doing, and the brighter they're fluorescing."

The research team saw an opportunity to use this new data to close the knowledge gap about crop growth, beginning with a major corn- and soybean-producing region of the U.S. Midwest.

"With the fluorescence breakthrough, we can start to directly measure photosynthesis instead of color," Guan said.

The fact that fluorescence can now be detected from space allows researchers to measure plant growth across much larger areas and over long periods of time, giving a much clearer picture of how yields fluctuate under changing weather conditions.

"One of the really cool things about fluorescence is that it opens up a whole new set of questions that we can ask about vegetation, and often times it's these new measurements that drive the science forward," said Lobell, who is the William Wrigley Senior Fellow at the Freeman Spogli Institute for International Studies and the Stanford Woods Institute for the Environment.

Next steps

The research team has already identified a number of potential uses of this approach by agricultural scientists, farmers, crop insurance providers and government agencies concerned with agricultural productivity.

If there is a day when the plant is really stressed, the fluorescence will drop significantly, Lobell said. Capturing these short-term responses to environmental changes will help scientists understand what factors plants are responding to on the daily time scale.

"That helps us, for example, figure out what we need to worry about in terms of stresses that crops are responding to," Lobell said. "What should we really be focusing on in terms of the next generation of cropping systems? What should they be able to withstand that the current crops can't withstand?"

At this early stage, fluorescence measurements are relatively low-resolution (a single measurement covers about 50 square kilometers) and because it is only collected once per day, cloudy skies can interfere with the fluorescence signal. For now, researchers have to supplement the data with other information and with on-the-ground observations to refine the measurements.

"Now that we have demonstrated the concept, we hope to soon be orbiting some new satellites specifically designed to make fluorescence measurements with better spatial and temporal resolution," Berry said.

The team plans to continue its research on U.S. crop yields while expanding measurements to other parts of the world.

"In the future, we hope to directly use this technology to monitor global food production, for example in China or Brazil, or even in your backyard," Guan said.

More information: Kaiyu Guan et al. Improving the monitoring of crop productivity using spaceborne solar-induced fluorescence, *Global Change Biology* (2015). DOI: 10.1111/gcb.13136

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