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Where Does Fire Retardant Fall in a Forest? Ask a Satellite

A plane drops a red slurry of fire retardant onto the Taylor Fire in Coconino National Forest in Arizona, in 2009. The U.S. Forest Service applied more than 28 million gallons of fire retardant between 2010 and 2020, according to the Los Angeles Times. *Credit: Coconino National Forest, Ariz./Flickr, CC BY-SA 2.0 (bit.ly/ccbysa2-0*

Here's an image that's all too familiar: A red cloud of fire retardant pours from the belly of a propeller plane onto a forest below. As climate change supercharges wildfires, fire crews are increasingly relying on fire retardants to create chemical breaks and contain fires. Knowing where the spray lands helps crews and scientists manage and study its effects.

A new remote sensing tool may help crews and scientists pinpoint the exact location of fire retardant by taking advantage of satellite images.

The tool "should be faster, cheaper, and better" than current methods, said Jerry Tagestad, a Pacific Northwest National Laboratory geographer who developed the technique.

Machine Learning in Action

The exact coordinates of where fire retardant lands depend on the wind and topography of the ground below. The red slurry loses its color within weeks under the Sun and washes away in the rain, making it difficult for scientists to study how it has affected the landscape.

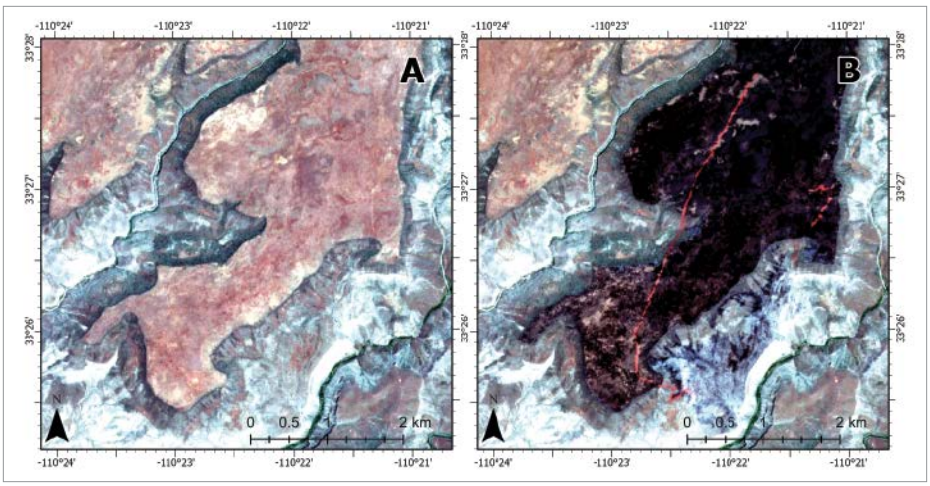
The U.S. Forest Service records a GPS location each time a plane releases fire retardant from its hatch. In some cases, fire crews fly a second plane to take photographs of the ground and trace drop locations by hand.

But restrictions to air space and other constraints make follow-up flights difficult during a fire.

To develop the tool, Tagestad and his colleagues trained a machine learning algorithm to locate retardant lines in images taken by the European Space Agency's Sentinel-2 satellite. They first sat down with satellite images and denoted areas with and without retardant. Using three machine learning classification models, the group then trained the computer to recognize those patterns in new images.

"We're taking the human out of the loop in terms of the mapping itself," Tagestad said.

The team tested the tool on images from seven fires in the southwestern United States that burned between 2020 and 2021. Five of



True color (a) before and (b) after images from the Sentinel 2 satellite reveal the red line of fire retardant dropped on the landscape during a fire in Blue River, Ariz., in 2020. Credit: Tagestad et al., 2023, https://doi.org/10.3390/rs15020342

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the seven study sites were in scrub and shrubland—a more accessible landscape for remote sensing—and two were in conifer forests.

The three machine learning models successfully identified fire retardant lines at the seven sites—the best-performing model captured 62% of fire retardant with 99% precision. "Using this method, you may be able to report [the fire retardant location] within a week after the fire," Tagestad said. The team published the work in the journal *Remote Sensing* (bit.ly/remote-sensing-fire-retardant).

Previous research by the Forest Service found that fire retardant likely affects some threatened and endangered aquatic life.

Applications for Aquatic Habitats

"This work offers a novel and promising way to map fire retardant more effectively," said conservation ecologist Karen Hodges of the University of British Columbia, who was not involved in the research.

NOAA Fisheries expert Joseph Dietrich, who studies fire retardant toxicity in Chinook salmon, called the remote sensing technique a positive step forward. He said the tool could be designed to detect accidental fire retardant drops over water automatically by identifying breaks in fire retardant lines captured in the satellite images. Previous research by the Forest Service found that fire retardant likely affects some threatened and endangered aquatic life, and other studies have suggested that fire retardant enhances weeds and harms Chinook salmon (bit.ly/NSF-fire-retardant).

Dietrich is interested in future versions of the tool estimating the quantity and concentration of fire retardant across a landscape to understand better the amount entering salmon habitats. Tagestad said the team is excited to expand the tool's capabilities, including remotely sensing the thickness of fire retardant across the drop zone, which could be used to calculate the amount of fire retardant entering sensitive habitats.

By **Jenessa Duncombe** (@jrdscience), Staff Writer

New Forecasting Tool Could Help Indian Farmers Plan Irrigation

Tropical weather can be capricious, torrid one minute and drenching the next. Such mercurial meteorology poses challenges to farmers, who need to predict soil moisture to plan irrigation. In a new study, scientists developed a tool for Indian farmers in the region of Nashik that provides weather forecasts and irrigation suggestions at the scale of a single farm (bit.ly/Indian-farms). The authors said it could be used across the region's 6,000 hectares of farmland—and potentially beyond.

"It is an excellent initiative, and the objective to help farmers manage farm-level operations better is no doubt a good one," said Madhavan Rajeevan, a meteorologist and former secretary of the Ministry of Earth Sciences in India who was not involved in the study.

"Decision Tools in an Uncertain Environment"

The 4-year study encompassed two entire growing seasons, including two monsoon seasons (called kharif) and two winter seasons (called rabi).

The scientists enlisted the help of 10 grape farmers in the district of Nashik who had soil moisture sensors. Using data from just two of the 10 available sensors and estimates from satellites, they quantified current levels of soil moisture. The decision to use a small subset of available data demonstrated that the method could be successful despite limited field observations.

The researchers then gathered weather-related data such as rainfall, temperature, humidity, and wind from the India Meteorological Department's hindcasts and forecasts. Weather forecasts typically reach 10-kilometer scales at best, so they integrated these data into a machine learning model that yielded small-scale predictions useful to farmers. The new method forecasted rainfall 1–3 weeks in advance and at the scale of individual farms.

Given current soil moisture and predicted rainfall, the study's authors then developed a tool that translated forecasts into irrigation decisions. The tool saved water compared with the farmers' traditional approach, which relies on personal notes of past rainfall, daily weather conditions, and how dry the soil looks. The new forecasting tool reduced water usage by 20%–45% during the monsoon season and by 17%–35% during the winter season.

"The real contribution [of the study] is developing decision tools in an uncertain environment," said Subimal Ghosh, a coauthor and a hydroclimatologist at the Indian Institute of Technology Bombay. "The idea is to provide a simple tool to help farmers, especially poorer ones who cannot afford [soil moisture] sensors, decide how much water they should use."

Still, Rajeevan was skeptical. For starters, using large weather circulation patterns to make farm-level predictions introduces inaccuracies. In addition, it's not clear how easy it will be to scale up this small case study.

Ghosh, though, remained resolute. "No model predictions are perfect," and finer resolutions always add errors and uncertainties, he said.

"The real contribution is developing decision tools in an uncertain environment."

Weather Predictions with Climate Change

Early-warning systems like the new forecasting system could gain prominence as the climate changes. For example, the World Meteorological Organization recently announced a global initiative to build and scale early-warning systems, especially in vulnerable regions of Africa, Central and South America, South Asia, and small island states.

The new study is just one step in that direction. The next, the authors said, is to develop an app that broadcasts climate advisories in local languages. "This is very important for Global South countries with resource constraints," said coauthor Raghu Murtugudde, a climate scientist at the Indian Institute of Technology Bombay. "Adaptation is about learning how to manage the unavoidable."

By **Rishika Pardikar** (@rishpardikar), Science Writer