

Using Drone Imagery to Better Manage Nitrogen in Almond Production: A Step Toward More Efficient Farming

By Kristin Singhasemanon

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Farmers need to use the right amount of nitrogen to help crops grow strong and healthy. However, too much nitrogen can be harmful — it can lower crop yields, pollute water supplies, and damage the environment. This challenge is especially true for California’s almond orchards.

In a new study, researchers explored different ways to measure nitrogen levels in almond trees using remote sensing — techniques that capture data from a distance, often using cameras on airplanes or drones.

The Problem at Hand

For years, farmers have applied nitrogen fertilizers uniformly across entire orchards without precise measurements. This “one-size-fits-all” approach often means applying more nitrogen

than needed, which can seep into groundwater and cause environmental and human health hazards.

In 2010, residents of the tiny Tulare County town of Seville began [receiving notices](#) about their water – they were told to boil their water before using. The next day, they were told to not drink, cook or wash dishes with the water, even if boiled.

At that time, the [LA Times reported](#) that 1 million people in California were living in places where tap water wasn't reliably safe to drink. The water was contaminated with excessive levels of nitrates, directly tied to agricultural runoff.

In 2012, Governor Jerry Brown signed [Assembly Bill \(AB\) 685](#) recognizing the public right to water. However, in the late 2010s, excessive nitrate levels were still consistently found in small central valley water systems, including almond growing areas. Complaints peaked again between 2017-2019, leading the state to establish the [2020 State Drinking Water Plan](#). While testing and compliance have increased, excess nitrate levels are still found in many private wells.

In addition to unsafe drinking water, excessive nitrogen runoff from farms transports these nutrients to waterways, acting as a fertilizer for native algae. The unnaturally high source of nutrients leads to harmful algal blooms, or HABs. This phenomenon depletes oxygen, kills fish, and often produces bacteria toxic to humans.

According to the [San Francisco Estuary Institute](#), the San Francisco Bay was traditionally resilient to algal blooms. However, incidents in the Bay and the Sacramento-San Joaquin River Delta began to increase in 1999 and surged in 2022. In that year, the [Natural Resources Defense Counsel](#) reported that pollution via runoff was the leading source of harm to water quality for surveyed rivers and streams.

While regulators are attempting to limit excessive nitrogen application and growers could save money purchasing less fertilizer, accurate measurement is still a challenge.

Traditional methods for checking nitrogen levels in trees are slow and expensive. They involve collecting leaf samples and sending them to a lab, where each test can cost around \$20. With the growing importance of sustainable farming practices, finding a fast, accurate, and affordable way to measure nitrogen is essential.

Exploring Different Methods

The study compared three main techniques:

Vegetation Indices: These are mathematical formulas that use light reflected from the trees to estimate nitrogen levels. While they are quick to compute, most vegetation indices did not perform well in predicting nitrogen in almond trees. Out of many indices, only a couple showed some promise, and even then, their accuracy was limited.

Machine Learning Models: These computer models learn patterns from data. The researchers tested several machine learning methods — including lasso, ridge, and elastic-net regression — on hyperspectral data (data that captures light across many narrow wavelengths). Some of these models, like elastic-net and lasso, achieved moderate success in predicting nitrogen levels. However, machine learning models often work best with the data they were trained on, meaning they might not perform as well when conditions change.

Physics-Based Radiative Transfer Models: Unlike the other methods, these models use the known behavior of light as it interacts with leaves. They simulate how light bounces off the leaves and changes as it travels through the tree canopy. One such model, called LESS, was used in this study to simulate almond canopies with various leaf biochemicals and generate synthetic aerial images similar to the ones obtained by drone. This simulated imagery was then used to determine the canopy structure and biochemicals of almond trees in actual drone imagery.

Key Findings

Crop Production Optimization: Past attempts to detect nitrogen levels in almond orchards using remote sensing only provided data at the plot level (Wang et al. 2022). For farmers to adopt targeted fertilizer applications and reduce nitrogen use, they need accurate measurements at the tree level and mapped spatial variability across their fields.

Environmental Impact: With a more precise nitrogen variability map, farmers could adapt their fertilization strategy to reduce excess nitrogen application. This means less nitrogen contamination of groundwater and surface water, reducing pollution and helping to protect local water quality.

Why It Matters

Solving this problem is good for farmers, human health, and our food. **Farmers can save money** by applying only the amount of fertilizer their trees need, leading to more sustainable and

cost-effective farming practices. Reducing excess nitrogen helps protect groundwater and local ecosystems, contributing to **safe drinking water** and non-contaminated freshwater fish. Almonds are a major agricultural product in California. More efficient nitrogen use means healthier trees and potentially **higher quality almond yields**, which is good news for both consumers and the agricultural economy.

This research marks an important step toward using advanced technology to solve everyday problems in agriculture. By finding new ways to monitor and manage nitrogen levels, scientists are helping to create a more sustainable future for farming in California and beyond.

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Read the full Precision Agriculture paper on [Springer Nature](#).

Project Researchers:

[Damian Oswald](#), Department of Environmental Systems Science, ETH Zürich, Zürich, Switzerland, Federal Office for Agriculture, Bern, Switzerland (visiting scholar at UCD)

[Alireza Pourreza](#), Director, Digital Agriculture Lab, Associate Professor, Department of Biological and Agricultural Engineering, University of California, Davis

[Momtanu Chakraborty](#), Ph.D. Candidate, Biological Systems Engineering, Department of Biological and Agricultural Engineering, Digital Agriculture Lab, University of California, Davis

[Sat Darshan S. Khalsa](#), Assistant Project Scientist, Department of Plant Sciences, College of Agricultural and Environmental Sciences, University of California, Davis

[Patrick H. Brown](#), Vice Chair, Crops and Ecosystems, Plant Sciences Executive Committee, Distinguished Professor, Department of Plant Sciences, College of Agricultural and Environmental Sciences, University of California, Davis