

Where can flooded fields help replenish groundwater?

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Credit: AI-generated image ([disclaimer](#))

In California, the amount of water exiting aquifers under the state's most productive farming region far surpasses the amount of water trickling back in. That rampant overdraft has caused land across much of the region to sink like a squeezed out sponge, permanently depleting groundwater storage capacity and damaging infrastructure.

The trend – and a 2014 mandate for sustainable groundwater management in the state – has ignited interest in replenishing aquifers in California's Central Valley through managed flooding of the ground above them. But until now there has been no reliable way to know where this type of remedy will be most effective. New research from Stanford University suggests a way to map precisely where and how to use [groundwater recharge](#) to refill the aquifers and stop the sinking.

Parts of the Central Valley sunk by as much as 28 feet during the first half of the 20th century, and in recent decades some locations have dropped by nearly 8 inches per year. Modeling in the new study, published in the peer-reviewed journal *Water Resources Research*, indicates the ground will sink by another 13 feet or more at some sites over the next 20 years unless pumping slows down.

Even under a scenario where pumping never exceeds the amount of water going into aquifers, the model predicts continued sinking as past overdrafts take their toll. "There is a time delay in the system," said geophysicist Rosemary Knight, senior author on the study and a professor at Stanford's School of Earth, Energy & Environmental Sciences. "The only way we can stop it is to be strategic about what we do with our available recharge water."

A perfect storm

In a normal year, water in canals, reservoirs and rivers is sufficient for most irrigation in the Central Valley, while aquifers provide a supplement. In recent drought years, however, surface supplies came up short and farmers contributing to the region's \$17 billion [agricultural industry](#) relied more heavily on groundwater.

"It's a perfect storm of an extensive agricultural industry combined with low precipitation, warm temperatures, the need for pumping

groundwater and an abundance of clay that is prone to subsidence," said Knight. Clays here that compact when pumped dry also tend to be rich in arsenic, which intensive pumping can release into water supplies. "So you have problems with water quantity and water quality," Knight said.



A helicopter flies over farmland near Tulare, California carrying equipment to transmit electromagnetic signals that will help gauge the structure of sand and clay layers underground. Credit: Aaron Fukuda

Recharge methods now in use or under serious consideration in California involve flooding fields or orchard groves during the winter months or creating year-round recharge ponds. "The key question is where does the water go?" Knight said. "If you're going to flood a farmer's field, you should be sure it's going to work."

Knowing where water will go underground depends on mapping the intricate channels of sand and gravel that interlace tightly packed clays and silts. In California, that information often comes from drilling contractors' reports to state regulators, which are expensive to acquire and do not cover areas between or beneath the drilled wells. As a result, the most common approach to dealing with subsidence is reactive. "If we are proactively managing then we can prevent unrecoverable storage loss," said lead author Ryan Smith, a professor at Missouri University of Science and Technology who completed the research as a Ph.D. student in geophysics at Stanford.

Above and below ground

The new approach, based on a marriage of two types of remote sensing data, could be applied across large agricultural regions at relatively low cost. Knight and Smith analyzed the structure of sand and clay layers that had been measured in a previous study by transmitting electromagnetic signals from a helicopter at three sites in Tulare County, about 45 miles south of Fresno, California. They also processed data from public satellite images to measure how much the ground had sunk.

"I realized that both of the datasets were linked to clay content," Smith said. "I thought, if there's a mathematical way to connect these two, then we could build a predictive model of subsidence." The study describes a method for adapting existing math and physics algorithms to integrate the two datasets into one model.

Only a sliver of California has been mapped with both types of remote sensing data, noted Tim Godwin, a senior engineering geologist with the California Department of Water Resources, which has supported Knight's efforts to expand airborne electromagnetic surveys in the state. But as these datasets grow, he said, coupling them with tools to predict sinking will help answer questions about the best ways to meet

sustainability goals. "Groundwater managers will be able to more accurately predict susceptibility to subsidence conditions and have greater confidence in proposed projects," he said.

According to Smith, subsidence in the coming years could be even more severe than the current model indicates if drillers deepen the region's wells to cope with future [water](#) shortages. "There are still deeper, largely untapped aquifers that, if pumped, would have a dramatic pressure loss," he said. "That would cause the clays to compact more than they do in the portions of the aquifer being used today."

More information: R. Smith et al. Modeling Land Subsidence Using InSAR and Airborne Electromagnetic Data, *Water Resources Research* (2019). DOI: 10.1029/2018WR024185 , doi.org/10.1029/2018WR024185

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