

Remote possibilities grow with redwoods

Tiny sensors a huge help in tracking trees' progress

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California forest ecologists are rigging redwood trees with networks of wireless sensors, using some of the tiniest such devices ever made to track the health of Earth's biggest living things.

Fifty "micromote" sensors, each packed with its own battery and transmitter within a weatherproof container the size of a pill bottle, now dangle like earrings from the branches of three trees growing in the UC Berkeley Botanical Garden's Mather Redwood Grove.

The sensors continuously monitor light, moisture and temperature at varying heights. The project has turned the stately grove in Strawberry Canyon, a popular setting for weddings and photo shoots, into a proving ground for a technology that experts say could revolutionize forest science.

"This opens up the ability to perceive how forests operate on a much more detailed basis than ever possible before," said Steve Sillett, a botanist and redwood specialist at Humboldt State University.

The project is a collaboration led by UC biologist Todd Dawson and computer scientist David Culler. The research is in an early phase, limited to calibrating the devices and working out kinks in the software. If everything works as hoped, more elaborate networks will sprout in wild redwood groves in Santa Cruz and Sonoma counties.

Ecologists have been struggling to come to grips with a disturbing die-off of California's signature tree throughout its range. Now, arrays of relatively cheap, easy-to-install micromotes may give scientists the ability to monitor entire tracts of forest to study the effects of climate change, pollution and clear-cutting.

NO MORE CLUMSY EQUIPMENT

Such experiments were impractical before, because scientists had to lug around suitcase-size equipment, weighing about 30 pounds per array, and string up miles of wire to generate the same kind of data.

The teeny sensors are programmed to "sleep" when not working, connecting themselves and maintaining their own networks, using an operating system known as Tiny OS.

The result: Streams of data transmitted every five minutes at speeds of 50 kilobytes per second for months at a time, for easy analysis on the ground. In the future, more elaborate sensors, perhaps running on tiny solar panels, are envisioned to monitor individual pollutants and nutrients.

"You want to measure lots of information in many places at the same time," Culler said during a recent demonstration of the equipment. "You want to fill the tree up with these things. . . You used to think about programming your computer. Now we're programming a whole tree."

TRYING TO HALT TREES' DECLINE

For the first time, scientists said, it may be possible to track the health status of scores of trees, strategically selected to cover whole forests and watersheds, and perhaps help rescue endangered redwood forests all along the coast.

"These trees are national treasures, and they are definitely in decline in their preserved range," said Sillett, who has collaborated with Dawson on projects. "In a lot of these forests, they look great, but when you climb up into the canopy, you find the tops are dying, and it's been going on at an alarming rate. . . . What we hope to find out is how far this is going to go, and is there anything we can do to ameliorate it?"

Already, Dawson and his crew of graduate students are picking up some hints from the early readouts in Strawberry Canyon.

The Mather Grove, planted in the 1930s, includes about 150 trees, some of them just a few yards away from a parking lot and busy Centennial Drive midway between UC's Memorial Stadium and the Lawrence Hall of Science.

The data loggers suggest that humidity in the interior of the grove ranges about 15 to 30 percent higher than around the perimeter, Dawson said. It's also 3 to 7 degrees warmer around the edges. Coastal fog, however, could give the outer trees a bigger hit of water, because those trees present the first surfaces the fog hits as it rolls up the canyon.

"The edge trees and the interior trees are seeing really different climatic variables," Dawson said. "Those trees that grow on the perimeter have a lot more of their canopy exposed to the sunlight and humidity and temperature swings. They are seeing really different conditions than trees inside the grove. So that opens up some really important questions."

CREATING OWN ENVIRONMENTS

All along the coast, redwood forests are becoming increasingly fragmented, creating more and more edges every day. Experts suspect this may be having some dramatic effects on the health of the redwoods, famous throughout the world not only for their stunning beauty but also for their ability to survive in foggy realms by drawing moisture from the air to supplement what they can suck out of the ground.

They essentially use their great height -- reaching to nearly 370 feet near the Oregon line -- to create their own microenvironments. That also creates habitat for scores of vulnerable species found nowhere else. Now, it seems these giants of the Pacific Coast, along with threatened animals such as the marbled murrelet, may be losing ground.

Experts hope to set up arrays of sensors to gain a detailed understanding of how the trees form their unique integrated communities, respond to changes in the weather, handle periodic droughts and other setbacks, and store and transport water through the seasons.

The Berkeley project is supported by the Intel Research Berkeley laboratory and the Berkeley-led Center for Information Technology Research in the Interest of Society, known as CITRIS.

The idea is to sample strategic parts of the forest for months at a time, at varying heights and orientations, so that scientists can track how the trees fare in different soil and weather conditions throughout the range.

Such ambitions were fantasies before the new remote technology came along. Sillett, for instance, had to find \$180,000 to wire just six trees, using 50-watt solar panels to run the hundreds of pounds of equipment, in one experiment.

The new devices are still being custom-built for a cost of about \$250 each, Culler said, compared with about \$3,000 for a conventional device with similar capabilities. Eventually the micromotes might be mass-produced, driving down costs in the same way digital cameras that once cost hundreds of dollars now are sold as disposables.

SENSORS CAN'T DO IT ALL

They can't work miracles.

Some measurements still will be hard to come by, such as sap flow, which requires drilling three holes into trees for each sensor. Installing the sensors, replacing their batteries and analyzing all the data they generate will require large investments of time and computer power.

Still, arrays of micromotes clearly have the power to extend the reach of researchers asking questions on an epic scale. And the technology is arriving not a minute too soon, experts said.

"The sad thing is the tallest trees on Earth are dying," said Reese Halter, a tree physiologist and president of Global Forest Science, a nonprofit research institute with offices in Marin County and the Canadian city of Banff.

Alberta, which is financing some of the latest redwood research.

"They are dying for a variety of reasons which we don't fully understand," Halter said. "It's important we understand the reasons. These are arguably the most magnificent things nature has yet to perfect."