Using construction cranes to reach above towering treetops, scientists are achieving a better overview of forest ecology and how trees contribute to global climate change

Sky-High Experiments

Plant ecologist Christian Körner of the University of Basel, Switzerland, goes to work by soaring into the sky on a construction crane. He and his colleagues squeeze into a four-person cage and, in 30 seconds, are carried up 30 meters. The crane operator guides the gondola to the end of the 45-meter-long boom and slowly lowers it, leaving Körner and his colleagues dangling just above the 30-meter-tall treetops of the Swiss forest they're studying.

Körner's first ride more than a decade ago was an eyeopener. "The canopy was not the green carpet we thought, but highly structured, with peaks, gullies, canyons, and deep gorges among some crowns," he recalls.

Once a novelty, cranes have become essential for sorting out forest dynamics, say ecologists. Most of a tree's photosynthesis occurs in its canopy—the upper leaves, twigs, and branches—and 40% of the world's terrestrial species live there. From their lofty perches on cranes, researchers have been counting species and studying leaf and tree physiology for more than a decade. More are now turning their attention to global change. Körner, for example, wants to know how forests capture greenhouse gases. On page 1360, he and his colleagues report findings from the first phase of a long-term experiment looking at carbon dioxide's effects in established forests. "[This study] is our first real glimpse of how mature forests might respond to increasing concentration of atmospheric carbon dioxide," says Kurt Pregitzer, an ecologist at Michigan Technological University in Houghton.

Körner is among several hundred ecologists, plant physiologists, taxonomists, and conservationists who have moved their studies off the forest floor to the more productive upper layers. These researchers work at about a dozen crane sites scattered around the world (see map, p. 1315). But if they can cobble together a relatively modest amount of money, these researchers have even more ambitious plans. In an effort called the Global Canopy Program (GCP), Körner and his colleagues are pushing to double the number of research cranes and train more students, scientists, community leaders, and educators in their use.

Lift off. Körner (*inset*) and his team do their work dangling 30 meters above the ground.

From the top

Linking the earth and sky, canopies harvest energy from the sun and create organic matter. They provide moist and dry spots, as well as warm and cold pockets, making possible a huge diversity of forest fauna. Canopies also play a role in global climate change, although researchers have yet to pin down exactly how. For example, trees suck in carbon dioxide for use during photosynthesis, whereas microbes release it by degrading fallen canopy leaves.

Although forest researchers are often willing to don climbing equipment to scale tree trunks or build walkways that sway among the branches, these strategies afford only a partial view of the canopy. The tops of trees either can't be reached from below or can't support the weight of people. In contrast, cranes offer a top-down perspective that forest researchers have wanted. In the past 15 years, "cranes have become the symbol of canopy research," says Kamal Bawa, head of the Ashoka Trust for Research in Ecology and the Environment in Bangalore, India.

In 1992, Alan Smith of the Smithsonian Tropical Research Institute (STRI) in Panama was the first to get this bird's-eye view of a canopy, using a 40-meter-high crane set up among the trees in a Panama City park. The vista was breathtaking and the view of the greenery below, stupendous. By swinging the crane's boom around in a circle and shuttling the gondola along its length and lowering the cage to different heights, researchers could finally get the big picture of a canopy.

A second crane was set up in 1997 in a different spot in Panama, a site where some 85 ecologists and taxonomists are now using a range of techniques designed to pin down the number and identities of arthropod species in the canopy. Established in 2003, the arthropod project now has 400,000 specimens and 1080 species in its archives. As it continues, researchers expect to find many thousands more specimens and large numbers of new species. Only with this many samples "can the many patterns of diversity, community organization, and functional roles of individual taxa [in the canopy] be understood," says forest ecologist Andreas Floren of the University of Würzburg, Germany.

CREDITS: CHRISTIAN KÖRNER

Published by AAAS

Once Panama's cranes began proving their worth—typically the investment requires several hundred thousand dollars per site—other groups began procuring cranes for temperate sites. In 1999, Körner used a helicopter to deposit a crane in a century-old Swiss woodland, whose trees tower 30 or more meters above the ground. Despite the importance of biodiversity studies, Körner took another tack with his crane. "A logical next step [was] getting involved in the larger process studies," including experiments related to greenhouse effects, he says.

Until Körner's project, those studying the forest effects of increased carbon dioxide had limited their attention to young trees—no taller than 16 meters and primarily in single-species plantations of sweet gum or loblolly pine. In these younger forests, ecologists pumped carbon dioxide from towers to blanket the young trees. However, they could not apply this technique to taller, more mature trees.

Körner overcame this drawback by placing 10 kilometers of drip irrigation tubing among the upper branches of a 500-square-meter plot. His team pumped carbon dioxide through the tubing, delivering 50% more than ambient concentrations to each tree. "My prime intention was to break the technological barrier that so far limited research to young, vigorously growing trees," Körner explains.

The carbon dioxide pumped through the tubing incorporated more than the usual amount of an unusual carbon isotope, distinguishing it from the gas absorbed normally from the atmosphere. In this way, Rolf Siegwolf and Sonja Keel of the Paul Scherrer Institute in Villigen, Switzerland, were able to track the fate of the extra carbon as it cycled through the forest ecosystem. At the same time, Körner's graduate student Roman Asshoff monitored tree growth. "This is certainly a much more realistic approach than studying potted plants or young trees in plantations," says Yves Basset, an STRI entomologist.

By focusing on mature trees and extending measurements to the ground, Körner was able to assess tree-soil interactions. Whereas young trees use extra carbon to speed up growth, mature ones don't, he and his colleagues report in this week's issue of *Science*. Instead, much of this carbon winds up in the roots, ultimately moving into the soil, where microscopic fungi take up much of it. Thanks to microbial activity, "this carbon is rapidly recycled to the atmosphere through the root zone," says Körner.

Different species of trees processed the extra carbon differently, but some trends were clear. Overall, carbon in the soil increased by 44%. Furthermore, the makeup of decomposing leaves changed. Lignin, a polymer that combines with cellulose to stiffen trees, dropped by 11%, whereas the amount of starches and sugars increased by 14%. As a result, decomposition sped up. The results highlight the critical connection between the canopy and the ground, says Pregitzer.

More labs with a view

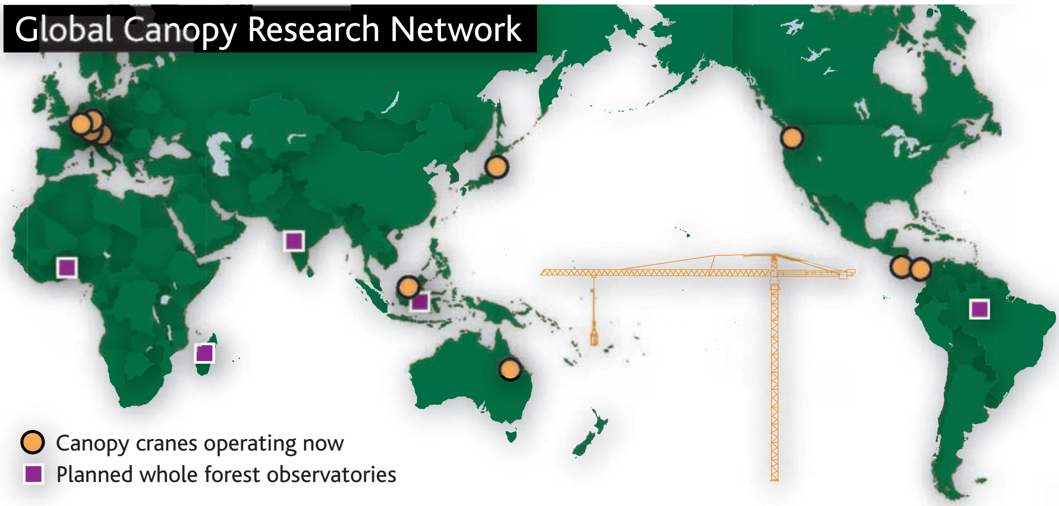
Körner now wants to help carry out larger-scale experiments with several cranes and to replicate the carbon dioxide work around the world in different forest types. About a decade ago, fellow forest ecologists created the International Canopy Network, which now includes more than 750 researchers from 62 countries. In the mid-1990s, the U.S. National Science Foundation (NSF) funded a canopy-research database that has fostered better collection, storage, analytical, and visualization techniques, including three-dimensional representations of the data.

The 4-year-old GCP, which is complementary to the International Canopy Network, is building on this momentum. It hopes to develop a more global view of biodiversity and climate change effects by doubling the number of existing cranes. Most of the new cranes proposed by GCP would be erected in tropical forests. Brazil, Ghana, Madagascar, India, and Malaysia have already signed on to host these so-called whole forest observatories.

The key, of course, is finding the money. Over the past decade, only about $4.5 million a year has been spent on canopy work worldwide. Coming up with $17 million over the next 5 years would pay for five of the 10 new observatories called for by GCP. The goal is to have the whole program up and running by 2020. In March, the United Nations Environment Program endorsed GCP's proposal, although to date it has only given GCP $30,000.

To qualify for the next level of United Nations support—about $500,000 for designing the sites—GCP must come up with $1 million. The five countries tabbed for whole-forest observatories have promised to help fund infrastructure and some of the research. The rest of the money must come from funding agencies of other governments or private foundations, says GCP head Andrew Mitchell.

The only U.S.-based crane canopy site, in Wind River, Washington, is supported by the National Forest Service (NSF). NSF also provides grants to individual canopy scientists, who pay a "bucket fee" of $185 a day. And the U.S. Department of Energy has a big project on climate change at the Wind River site.



Lofty goal. Placing cranes in new places will fill out the network of existing crane research plots and lead to better integration of canopy studies.

SOURCE: GLOBAL CANOPY PROGRAM

The uncertain financial picture for GCP's plan isn't preventing some hosts of the new whole-forest observatories from forging ahead. The Indian government has provided the Ashoka Trust with seed money to start a canopy program in western India, and last week, researchers held a planning meeting. Canopy researchers elsewhere are tweaking their activities to conform with the whole-forest observatories protocols.

Thanks to these efforts, "the focus on canopy research will change from the more-or-less isolated investigations to globally coordinated projects with comparable methods," says Martin Unterseher of the University of Leipzig, Germany. This integration is essential, he adds, if scientists hope to ever understand the relationship between forest biodiversity and global change.

–Elizabeth Pennisi