

Sustaining Forests in a Changing World

HALF-COVERED IN TREES AND BLESSED— or cursed—with hot, dry summer days, Greece is used to wildfires. Yet the blazes that swept across Greece last summer were the worst in living memory. According to the European Commission, 64 people died and about 180,000 hectares of forest and agricultural land were burned in just the most severe of the blazes, which raged between 24 and 30 August. It was, says Andreas Drouzas, a Greek forest evolutionary geneticist at Aristotle University of Thessaloniki, “something that both professionally and personally someone cannot take out of his or her mind.”

While some tree species have evolved to regenerate naturally after fire, last summer’s fires destroyed fir trees in the mountainous Peloponnesus peninsula and in Mount Par-nitha near Athens that are not normally affected by fire. “The fir forests need hundreds and even thousands of years to be established, and they don’t have any mechanism to survive or overcome the fire,” Drouzas says. “That is because the fires at high elevations were a rare event, but due to the climate change nowadays, the fires burned down even forests of high elevations.”

Unfortunate events such as these may have some positive scientific consequences. Stresses on ecological systems, and the global changes and human activities that cause them, nudge the science of forests in new directions, creating professional opportunities. “As the forests have decreased and the society has become more ... aware of the consequences of loss of natural ecosystems and biodiversity,

and the associated decline of ecosystem services, there has been more and more interesting research in forest ecology, and this trend will continue,” says Kamaljit Bawa, a tropical forest evolution and conservation ecologist at the University of Massachusetts, Boston.

An evolving field

Over the past decade or so, the focus of ecology has shifted from studies of undisturbed ecosystems to the impact of human activities, propelling some subfields—including forest ecology—into a period of renaissance. Because forest ecosystems help maintain water and air quality, regulate the local and global climates, protect soils from erosion, and host the greatest biodiversity on land, they are central to most of today’s global environmental issues.



Sustaining biodiversity. Andreas Drouzas wants to create a gene bank so that forests in the Peloponnesus peninsula can be restored after fires.

In Europe, the European Commission has made environmental research one of its 10 thematic priorities in its 2007–13 funding framework program, earmarking nearly €1.9 billion for environmental research from a €50.5 billion budget—a sharp increase from the previous framework. Forest research is expected to grab a healthy chunk of Europe’s spending on environmental research; the new framework offers many topics on which forest ecologists could submit proposals, Drouzas says.

In the United States, National Science Foundation (NSF) funding for environmental research and education increased by about 40% between 2000 and 2004, after which it flat-lined. But Susan Stafford, a forest statistical ecologist at the University of Minnesota, St. Paul, and chair of the NSF Advisory Committee for Environmental Research and Education, says a large-scale research program focused on the sustainability of complex environmental systems is in the pipeline. “We are very optimistic that the funding for all environmental fields” will increase after 2010. And “forestry [is] a very major component in all of environmental and ecosystem sciences,” she says.

Dirty boots and other basics

Working in forest ecology requires a special set of skills: a foundation in biology, chemistry, physics, and mathematics; a deep understanding of ecological principles and forest ecosystems; and enough knowledge about botany and taxonomy to recognize known species and new ones. It also requires

an array of field techniques for measuring forest structure, soil chemistry, and climatic conditions, for example.

Forest ecologists also need “a lot of grit,” says Catherine Cardelús, a tropical forest canopy ecologist at the University of Florida, Gainesville. Cardelús commonly puts on a 15-kg backpack filled with climbing gear, hikes 4 hours into the middle of the forest, then goes up trees. “You need to be able to handle that,” Cardelús says, while remaining flexible—and not just literally. “We are constantly updating and revising the situation” as the work and conditions require, she says.

Getting along in forests requires survival skills, especially in the tropics. You have to know how to avoid the pervasive snakes and spiders, for example. Then there’s the risk of getting lost, being stung by a swarm of bees, or being urinated on by howler monkeys. “The canopy is where they live,” and monkeys will yell and throw things at you, and even urinate on you, if you don’t leave their tree and let them eat in peace, Cardelús says.

In such a hazardous world, caution reigns, and remaining safe requires some technical and physical skill. “I can drop out of a tree in 15 seconds in case I am swarmed by bees,” Cardelús says. “What I do is inherently dangerous, but I am very safe.”

The best way to acquire the needed skills is by getting your boots muddy. “Volunteer to join a field trip expedition, just to get some experience to see what is involved rather than just being in lectures or lab work,” says Yadvinder Malhi, an ecosystem scientist working on tropical and temperate forests at Oxford University in the United Kingdom.

You may also have to make some personal sacrifices. Most forest ecologists travel extensively and collect data in the wild for several months at a time. “You need to love being in the woods, without much of what we take for granted in our civilized world,” says Jérôme Chave, a tropical forest ecologist at the Laboratory for Evolution and Biological Diversity in Toulouse, France. “It is tiring and ... difficult to combine with a full personal life.”

An interdisciplinary skill set

Forest ecologists use approaches ranging in scale and complexity from molecules and genes, through populations and communities, to whole ecosystems and the biosphere. Researchers may have to weave together aspects of the forest as diverse as population and community dynamics, plant physiology, microbiology, entomology, soil physics and chemistry, hydrology, geography, and climatic and geographical conditions. No one has the skills to do even part of this alone, so



A woman ascending. When Catherine Cardelús started out, most “people who were climbing were men.”

A SELF-MADE CLIMBER

Catherine Cardelús, 36, discovered her passion for tropical forests while listening to a teacher describe the astounding diversity of rainforests. “I decided to be a rainforest [ecologist] without having seen” a rainforest, Cardelús says. The following summer, she flew to La Selva Biological Station in Costa Rica on a summer fellowship and climbed her first tree. She “got so excited about going up that I didn’t think about how to get down,” she says. As she reached the first branch 15 m above the ground, “I looked up into it and I saw another forest.”

Cardelús has since taught herself how to move freely up and down trees, but she’s still struggling to understand a key scientific question: Why is there so much plant diversity 50 m above the ground?

After obtaining her B.A. in biology from Barnard College in 1996, Cardelús did a Ph.D. on the distribution of vascular epiphytes—plants that grow on other plants—in tropical forests in the Department of Ecology and Evolutionary Biology at the University of Connecticut, Storrs. Part of her project involved looking at how microclimate affects the way plants are laid out on the branches of individual trees. She built networks of sensors to monitor light, humidity, and temperature along the branches, powering them from the ground with a motorcycle battery. She studied the distribution of epiphytes at 500-m intervals along a 2900-m elevation gradient between La Selva and the Volcán Barva in Costa Rica.

In 2003, Cardelús took a postdoc at the University of Florida, Gainesville, to study the nutrient dynamics of epiphyte communities. Together with her husband—a functional plant ecologist—and their 9-month-old son, she spent the first year of her postdoc at La Selva Biological Station comparing soil and canopy nutrient sources.

Cardelús splits her time between the United States, where she does a lot of analytical and biochemistry lab work quantifying nutrient dynamics, and field trips. Her eldest son, now 5, routinely accompanies her to Costa Rica, and her second son, age 2, will come along the next time.

Starting in July, Cardelús and her husband will each take assistant professorships at Colgate University in Hamilton, New York, where she plans to extend her research to nutrient dynamics in relation to local pollution and climate change. “It hasn’t been until recently that I ... and other canopy researchers ... have had enough baseline data to begin addressing these questions,” she says. Nowadays, “most researchers, especially forest ecologists, are incorporating climate change impacts into their research, both for funding reasons and because climate change is having a serious impact on forest ecosystems.”

Of Hispanic origin, Cardelús is keen to share her passion for forest canopies with younger scientists and to nurture minority students and women in particular. “I had more barriers to overcome,” she says. In her early days, most “people who were climbing trees were men. I wasn’t even considered a serious player” at the time.

—E.P.P.

The big picture. Kristina Stinson's research on invasive species requires "small-scale, meticulous work."



MEASURING THE IMPACT OF INVASIVE PLANTS

"I have always been fascinated by the complexity of nature and the way that [organisms] interact with one another," says Kristina Stinson, 38, a plant population biologist at Harvard Forest in Petersham, Massachusetts.

After obtaining two bachelor's degrees, one in literature and languages and another in natural sciences and mathematics, Stinson did a Ph.D. at the Department of Ecology and Evolutionary Biology at Princeton University, conducting her research on how global warming influences the flowering time of alpine plants on the verge of extinction at the Rocky Mountain Biological Laboratory in Crested Butte, Colorado. After graduating in 1998, Stinson took a postdoc at Harvard University, where she studied the dynamics of ragweed populations in elevated atmospheric carbon dioxide levels as well as the physiological processes that turn plants into invasive species outside their home ranges.

Stinson's fieldwork took her to Harvard Forest, where she applied a population perspective to studying how invasive plants affect forest ecosystems. They "really change the way the forests work because they form very dense populations of single species and often replace or displace the native plant," Stinson says. After a couple of years working on this topic as a research associate at Harvard, she was offered her current staff position at Harvard Forest.

Stinson's work on garlic mustard—an invasive plant able to kill fungi essential to the growth of tree seedlings—involves "crouching down in the woods [with] a clicker counter to count individuals" at 1-by-1-meter sampling sites all around New England. It is "small-scale, meticulous work." She brings soil samples back to the lab to monitor the presence of fungi and quantify how much garlic mustard affects the growth of tree seedlings in greenhouses. "It really spans the whole spectrum of fieldwork to lab work," she says.

Stinson's work has implications for forest management. "It's very important to be able to demonstrate when an invasive plant is actually having a negative impact and what the negative impact is, because forest managers are working to manage an ecosystem that has all kinds of management problems and limited resources," she says. She has also done research and management advisory work for U.S.-based conservation charity The Nature Conservancy. It's "very gratifying to see that your research has the potential to have an impact," Stinson says.

—E.P.P.

young forest ecologists need to be "doing their homework, ... building the international partnerships with colleagues that allow them to ... create very realistic and vigorous scientific ... projects," says Stafford.

Forest ecology depends on increasingly sophisticated technical, quantitative, statistical, and computer skills. New data-gathering platforms like the National Ecological Observatory Network and the international Global Earth Observation System of Systems are coming online, and growing quantities of data, spanning ever-larger geographical and time scales, await analysis. Researchers need a strong technical understanding of tools like geographic information systems, distributed sensor networks, and the Global Positioning System "to take most advantage of the enormous volumes of remotely sensed data," Stafford says. Advanced computer-modeling skills have also become essential as researchers try to understand the role of forests in global dynamics and to predict the impact of environmental pressures on forests. Some experts, including Malhi, believe there aren't enough scientists who can combine biological insight with competence in modeling the physics of biological systems.

Social science enters the picture as well. When looking at how local usage may drive certain forest species to extinction, for example, scientists must "not only focus on the population dynamics of that species but also on how people harvest these species, and what social and economic interactions govern the harvesting and use of these species," Bawa says. "In order to do that, you have to be aware of the methods that are used by social scientists" to study social institutions and economic determinants of human behavior, he adds.

Some institutions are now bringing diverse disciplines closer in efforts to provide such broad training. The College of Forestry at Oregon State University, Corvallis, for example, participates in a graduate program in ecosystem informatics and another in environmental sciences that spans life, physical, and social sciences. The Department of Environmental Science, Policy, and Management at the University of California, Berkeley, offers a graduate program that integrates the natural and social sciences and allows students to work on forests. Last year, the Ashoka Trust for Research in Ecology and the Environment, a research, policy analysis, and education nonprofit Bawa founded in Bangalore, India, launched a doctoral program in conservation science in collaboration with Manipal University. The program is for natural and social scientists interested in working on forests, among other ecosystems.

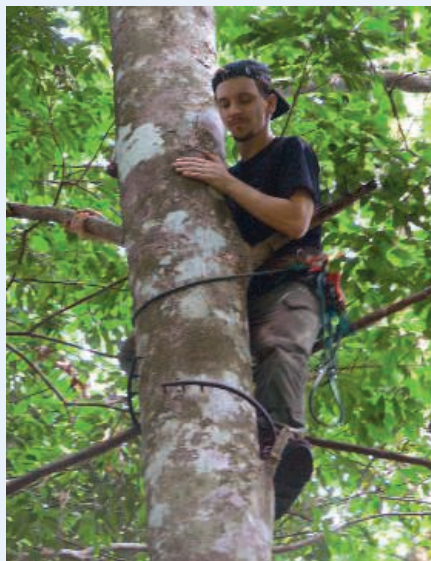
AN ADVENTUROUS PHYSICIST

When Jérôme Chave stepped into a tropical forest for the first time, “I was even unable to identify a weed in my backyard at home, and the idea that hundreds of plant species were coexisting peacefully in tiny areas of forest astounded me,” he says. The impact prompted Chave to leave theoretical condensed matter physics to focus on tropical forests. Ten years later, Chave, 35, runs his own forest ecology group at the Laboratory for Evolution and Biological Diversity in Toulouse, France.

Chave grew up in a family of artists with no particular interest in nature, he says. After obtaining a postgraduate diploma in mathematics and physics from the École Centrale in Paris, he pursued a Ph.D. on the statistical properties of complex systems at the French Atomic Energy Commission Laboratory of Condensed Matter Physics in Saclay, near Paris. Halfway through his Ph.D., Chave’s adviser met some ecologists investigating paleoenvironments in Africa and South America. “They had the sense that modelers could bring a more synthetic view in their problems. We had a sense that we would have a model to study complex systems that would be a lot more fun than particle systems,” Chave says.

Before he knew it, Chave was walking in a pristine rainforest in French Guiana designing a model of tree population dynamics. “I was blown

Changing scales. Jérôme Chave left theoretical physics to study tropical forests.



away by the tremendous complexity and amazing diversity” of forests, he says. Starting in 1999, Chave did a postdoc in the Department of Ecology and Evolutionary Biology at Princeton University. There, he used computer modeling and field data to elucidate how forest ecosystems store and recycle carbon and to compare alternative theories for species coexistence.

Since coming back to France in 2001 to take a position at the French National Center for Scientific Research, Chave has continued to cross disciplines. On his team, biologists and mathematicians work together on projects that encompass climate change, biodiversity, community phylogenetics, population genetics, and tropical-tree defenses.

Chave learned the ecology, molecular biology, and chemistry he needed by talking to colleagues, going to seminars, and reading papers. Botany wasn’t so easy. “I spent a long time in the field trying to learn my species. ... If you don’t start at the age of 3, you don’t know how to look at nature in the proper way.”

Chave, who every year spends about 2 months in the field, learned how to live and work in tropical forests by doing. Still, doing botany in the tropics means climbing 50-m trees to collect leaves, as some of them cannot be identified from the ground. For someone who gets dizzy with height, “it was a big challenge,” Chave says.

Once beyond the most adventurous aspects, “you realize how quiet it is to be in a tropical forest rather than in an urban area full of stressed people and telephones. You just enjoy the monkeys around and the birds. It’s great.”

—E.P.P.

But at most institutions, acquiring the necessary skills is “a question of the student taking the initiative to familiarize him[self] or herself with other areas [by] perhaps having an interdisciplinary master’s or Ph.D. committee and taking ... courses in disciplines other than the ones that [they] are doing,” says Daniel Simberloff, a community ecologist working on forests at the University of Tennessee, Knoxville. Other proven techniques include attending seminars in other departments and joining the relevant scientific societies.

But forest ecologists must also remember to focus their work narrowly. “It’s such an interesting field that it’s often hard for students to narrow their focus and to do a doable project. ... At any level, it’s important to home in on what questions you are going to focus on,” says Kristina Stinson, a plant population biologist at Harvard Forest in Petersham, Massachusetts.

Engaging the human part of the ecosystem

Many forest researchers consider feeding their results into the global political debate a part of their jobs. “Scientists, because they have certain expertise, are almost obligated to provide that information,” Simberloff says. That means learning “to effectively communicate the results to a wide array of audi-

ences, not only scientists but people in the media, citizens, and of course policy- and decision-makers,” Bawa says.

Dealing with such sensitive issues is a tricky game. You have to engage in the debate, yet expressing personal opinions can be hazardous. Make sure you base this participation on well-grounded, credible, and objective science, Malhi says: “There is an important distinction between a concerned, informed scientist and a partisan lobbyist.”

Opportunities

Many experts see pockets of growth in the forest ecology field. “The job market remains strong, with expanding opportunities in invasive species ecology, ... rare and endangered species, fire ecology, and climate change ecology,” Robert Teskey, a forest ecophysiology who earlier this year chaired a selection committee in the Warnell School of Forestry and Natural Resources at the University of Georgia, Athens, writes in an e-mail to *Science*. In addition to “forestry and natural resources programs in the U.S., ... many other programs hire ecologists who focus their research in forest ecosystems,” he adds. Michigan Technological University in Houghton, for example, last year launched

a multidisciplinary hiring initiative to fill 10 new tenure-track positions in sustainability science, with interactions between forests and the atmosphere among the research themes.

Despite these signs of strength, “it’s really competitive at the moment,” says Cardelús, who has just been awarded a position in the Department of Biology at Colgate University in Hamilton, New York. Teskey acknowledges that his university has “raised expectations for new hires at the assistant professor level and [is] expecting individuals to provide a stronger résumé with evidence of quality peer-review[ed] journal articles, success in obtaining grant funds, and experience in teaching.”

Still, “it’s a very interesting position and time to be a forest ecologist,” Stafford says. The rewards, Bawa adds, “include the knowledge that one can potentially make fundamental contributions to the resolution of some of the most pressing issues faced by ... society, the sheer joy and privilege of working at some of the most pristine places on earth, the satisfaction of enjoying natural as well as cultural diversity, and the opportunities of learning about different knowledge systems as these pertain to forests.”

—ELISABETH PAIN

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