COMPASS

perspectives & tools to benefit southern forest resources from the southern research station

issue 10

What do forests have to do with global climate change?

inside... the science

Cover photo: Computer painting by Rodney Kindlund from a photo from Click-Art 200,000 Graphics Reference Book ©1997 Brøderbund

COMPASS
Science You Can Use!

February 2008 — Issue 10

perspectives and tools to benefit southern forest resources

COMPASS is published by the Science Delivery Group of the Southern Research Station (SRS), Forest Service, U.S. Department of Agriculture. As part of the Nation's largest forestry research organization—Forest Service Research and Development—SRS serves 13 Southern States and beyond. The Station's 130 scientists work at more than 20 units located across the region at Federal laboratories, universities, and experimental forests.

Future issues can be obtained by returning the postcard included in this issue.

www.srs.fs.usda.gov

Email: zhoyle@fs.fed.us, cpayne@fs.fed.us
Telephone: 828-257-4392
Editors: Zoë Hoyle, Science Writer, and Claire Payne, Technical Information Specialist
Art Director: Rodney Kindlund
Contributing Staff Writers: Carol Whitlock, Livia Marqués, and Perdita Spriggs

The mission of the Southern Research Station is to create the science and technology needed to sustain and enhance southern forest ecosystems and the benefits they provide.

ISSN: 1931-4906

Printed on recycled paper
Printed with soy ink

Free-air CO_2 enrichment (FACE) site in Duke Forest near Research Triangle Park, NC. FACE sites across the United States are used to study how forests will store and cycle carbon under climate change. (Photo by Chris Maier, U.S. Forest Service)

Forests & Global Climate Change

by Allen Solomon

Forest Service scientists have been studying global change and its effects on forests and ranges informally for many decades, and formally since passage of the U.S. Global Change Research Act of 1990. More recently, the Forest Service as a whole has come to recognize the threats and opportunities involved with maintaining ecosystem services and products under rapidly changing climate and climate variability. Forest Service Chief **Dale Bosworth**, now retired, identified global change as "the greatest threat to our natural resources in the 21st century . . . ." Our present Chief, **Gail Kimbell**, has named climate change and related water issues as two of the three greatest challenges facing the Forest Service.

So, if we know in general what the threats of a changing climate are, and we know how plants and ecosystems respond to changing climate and atmospheric chemistry, why do we not simply implement the management actions we have available to reduce the risks and take advantage of the opportunities global change presents? The answer, of course, is that we do not yet know the threats well enough, particularly at the local level where actions can be taken—and surprising to some—we don't really know how plants and ecosystems respond to changing climate and atmospheric chemistry that well.

I first became involved in global change research a little over 30 years ago at Oak Ridge National Laboratory. Then, the fundamental question to be solved was whether the Earth would become a source or a sink for carbon as climate and atmospheric chemistry continued to change.

The answer to this question is critical for defining the nature of the risks we face in the future. If global warming and increases in atmospheric CO_2 result in the Earth sequestering and storing more carbon (say, because trees cover more area and CO_2, a plant nutrient, makes them grow at greater densities than today), the impacts from climate changes forced by excess atmospheric CO_2 will be considerably less than our calculations suggest. On the other hand, if warming forces the stored carbon from forests and rangelands (say, because today's trees become climatically "obsolete" and undergo widespread dieback), then the problem becomes even more challenging than we thought, with more CO_2 begetting more warming, more warming begetting still more CO_2, and so on.

> ***"...things we can and must do in response...our options include protecting the existing carbon sink through forest conservation and increasing carbon sequestration through reforesting degraded land, improving forest health, and supporting sustainable forest management...forest biofuels for energy and the substitution of wood for manufactured products are the other opportunities for managing carbon."***
>
> *—Gail Kimbell, Chief, U.S. Forest Service*

In the intervening 30 years since 1977, when we began obtaining research grants to study this issue, much has been learned about the global carbon cycle. There is even a "current" answer to the question: The vegetation of the Earth is now a net carbon sink and should continue sequestering carbon at least until about mid-21st century, when it is expected to become "carbon saturated."

Yet, this outcome rests on global vegetation models that assume, rather than know, the answer to the question we were asking in 1977: They assume that warming will permit trees to cover more area, and that CO_2 will enhance vegetation density. At the same time, the models do not simulate such things as the consequences if trees undergo significant dieback when the climate they require (their "climate envelope") moves away to higher latitudes and altitudes. Yet how we manage the land to reduce climate impacts depends entirely on that unanswered question.

One reason the question has not been answered is that we still do not yet know if, or how, increasing atmospheric CO_2 will change the climate envelope to which each species is thought to be limited. For example, Forest Service research has shown that tree seedlings grown under higher concentrations of CO_2 more efficiently use water to photosynthesize; that is, they can sequester more carbon for every gallon of water they use. If this process works the same way in wildland vegetation as in controlled experiments, the moisture limits of the climate envelope for say, loblolly pine,

Sea levels along the South Carolina coast have already begun to rise as a result of warming temperatures. (Photo by Zoë Hoyle, U.S. Forest Service)

could be expanded, permitting loblolly to grow in more arid climates, or to withstand greater droughts where it grows today.

Conversely, CO_2 has increased about 30 percent in the last century, with little or no tree growth effect detected, while forest diebacks have become more common, especially from climate change-induced increases in insects and wildfires. Should we manage our forests on the expectation that the carbon "carrying capacity" will increase on the land, or that it will decrease? That today's forests will emit less water to the atmosphere in the future, or will lose more water during hotter summers?

These are critical questions from the past 30 years that are still not answered satisfactorily today. Yet, they must be answered to meet the climate change and water challenges Chief Kimbell recently enunciated, and that Forest Service scientists at the Southern Research Station have focused on answering.

In this issue of *Compass*, you can read about expectations for future change in southeastern climate, forests, and life. Consider the article on research into the ability of forests to sequester more carbon under higher CO_2 concentrations in the future entitled "That Carbon Dance." Another article describes some surprising results of long-term CO_2 fumigations of trees in the Duke Forest. You can examine new research on models that calculate future water supplies in the region. Other SRS research reviewed delves into implications for Coastal Plain ground water of rising sea levels, also induced by climate change. These studies aim at the most important uncertainties in global climate change and their implications for our local and regional environmental issues.

Allen M. Solomon, Ph.D. is the National Program Leader for Forest Service Global Change Research in Washington, DC.

PLANTS IN PERIL: Local Solutions

Many plants now listed as threatened or endangered will be seriously affected by further climate changes. Take, for example, the Kentucky lady's slipper (*Cypripedium kentuckiense*)—a stately perennial plant with the largest flowers of any lady's slipper known. Though its range includes much of the Southeastern United States, the plant occurs in widely separated populations, some very small.

In the 600,000-acre **Kisatchie National Forest** (KNF) in Louisiana, populations of Kentucky lady's slipper are found on two sites, with a total of five plants. A collaborative effort to restore the plant to the region began with the efforts of Kevin Allen, a local high school student and amateur botanist who, with the help of an expert orchid grower, produced seedlings from an orchid he found flowering on one of the Kisatchie sites.

Recognizing the opportunity to restore the orchid on more sites in the national forest, but lacking the expertise to grow seedlings, KNF approached the Central Louisiana Orchid Society, which got a research and conservation grant from the Southwest Regional Orchid Growers' Association to buy plantlets for restoration outplanting. With additional grants from SRS and the **Forest Service Southern Region**, over 700 seedlings are being produced.

The success of this initiative has led to a similar cooperative effort between the **Texas National Forest** and Houston Orchid Society. "Although this is not a traditional species for the Forest Service to restore, it shows how the interest of just one person can lead to a collaborative process to restore a threatened species," says **James Barnett**, SRS emeritus scientist involved in the project. *—ZH*

For more information:

James Barnett at 318–473–7214 or jpbarnett@fs.fed.us

*A collaborative restoration outplanting of Kentucky lady's slipper (*Cypripedium kentuckiense*) in the Kisatchie National Forest in Texas shows how people and groups can work together to respond to changing conditions. (Photo by Charles T. Bryson, USDA Agricultural Research Service, www.bugwwod.org)*

THE FATE OF SOUTHERN FORESTS:

Impacts of Climate Change and Variability

by Livia Marqués

Today, forests comprise 214 million acres, or more than 65 percent, of the South's land area. Southern forests provide a wealth of services and products—clean air and water, terrestrial and aquatic habitat, cultural and aesthetic values, recreational opportunities, carbon storage, timber, pulpwood, fuel, food, and medicinal plants. What of their future? The wealth of products and services provided by our forests depends on their biodiversity and function.

Is America's "wood basket" in jeopardy? The Southeast currently produces about half of the country's timber supplies, supporting over 700,000 jobs in forest industries.

Human activities have changed the amount of greenhouse gases in the atmosphere. The overall effect on the Earth's climate has been a warming influence, referred to as global warming. It is important to note that although warming is a global occurrence, the impacts of increasing temperatures will vary from region to region, just as the weather varies. In the South, the key issues impacting forests will be changes in sea level, disturbance events such as wildfires and drought, and effects on biodiversity, productivity, and socioeconomic values.

Sea level rise, one of the more certain consequences of climate change, has already had significant impacts on southeastern coastal areas. Vast stands of forests are dying along the Gulf of Mexico shoreline due to saltwater intrusion. Since 1852, when the first topographic maps of the region were developed, high tidal flood elevations have increased approximately 12 inches. Bald cypress and live oak mortality has occurred as far inland as 30 miles. The resulting stands of dead, sun-bleached trees are locally referred to as "ghost forests." Rising sea level is one of several factors that have caused the loss of over one million acres of wetlands in Louisiana since 1900. Other processes contributing to these losses include subsidence due to ground-water withdrawal and natural sediment compaction, wetland drainage, and levee construction.

Expect Extreme Events

Prone to natural weather disasters, the Southeast will be further impacted by changes in temperature and precipitation that alter the frequency, intensity, duration, and timing of disturbances such as fire, drought, invasive species, insect and pathogen outbreaks, and hurricanes. Although disturbances are a natural and integral part of forest ecosystems, it is the changes in disturbance regimes that will have the greatest impact on forest systems. Climate change alters the interactions between the ecosystems and the disturbances by causing disturbances that exceed their natural range of variation. This variability can cause extreme changes in the structure and functions of our forests. "Climate variability causes much more damage than climate change," says **Steve McNulty**, leader of the **SRS Southern Global Change Team**, "and this will likely be the case for the next several decades."

Over the past 100 years, intense precipitation events have increased across the South. This trend is projected to continue, raising the likelihood of flooding and erosion. Climate and ecological models predict the seasonal severity of fire hazard will increase by 10 percent over much of the country, with larger increases in the South. A single disturbance such as fire has multiple effects on forest ecosystems, including the acceleration of nutrient cycling, mortality of individual trees, shifts in succession, loss of seed banks, loss of soil nutrients, changes in soil surface organic layers, and changes in underground plant root and reproductive tissues. It is difficult to predict the interactions between climate changes and multiple disturbances, partly because many disturbances are cascading. Drought often weakens tree health, leading to insect infestations or diseases; these in turn promote future fires by increasing fuel loads, then fires promote future infestations by weakening tree defenses.

"Although fuel reduction measures may help to reduce the size and intensity of wildfires, climatic drivers play a much greater role in fire risk than does fuel loading." —*Steve McNulty*

THE FATE OF SOUTHERN FORESTS

We understand even less about climate change interactions when an ecosystem experiences multiple disturbances at once. When a new disturbance strikes a system that is still recovering from a previous disturbance, the compounded effects can lead the system to a new ecological state. Invasive species can further complicate these interactions due to their ability to modify existing disturbance regimes or introduce entirely new disturbances.

Biological Diversity

Currently considered among the highest in North America, the biodiversity of southern forests will clearly be impacted by climate change, although the effects are difficult to predict. Some species are likely to expand while others decline, and entirely new communities may form. Human activities have undeniably modified the quality, amount, and configuration of habitats in the South. The expansive ranges of forest community types encountered by settlers, including spruce-fir in the Southern Appalachians, Atlantic white-cedar in Virginia and North Carolina, and longleaf pine in the southeastern coastal plains, have been reduced to less than 2 percent of their presettlement ranges. Not surprisingly, many species that depend on these ecosystems, such as the longleaf pine-dependent red-cockaded woodpecker, are currently in peril. At the same time, species associated with human-dominated landscapes have greatly expanded and some, such as deer, are now so abundant that the primary concern is population control.

Special forest products, such as ginseng, may be particularly susceptible to climate change impacts. The loss of these products would ripple through local economies. Research conducted in West Virginia found a strong positive correlation between ginseng harvests and the State unemployment rate.

Ecological models using several different climate scenarios indicate changes in the location and area of potential habitat for many tree species and plant communities. According to one model, American beech and sugar maple are predicted to gradually shift north into Canada, leaving only a few isolated communities in the United States. Loblolly pine and sweetgum are also expected to shift as far north as New Hampshire and Maine. How well plant species adapt to changes in their potential habitat is largely dependent on their dispersal abilities. Invasive species that disperse rapidly are likely to find many opportunities in newly forming communities and expanding urban areas.

More or Less Forests

Between 1980 and 2000, population growth in the South was faster than for the Nation as a whole. Urbanization could eliminate about 12 percent of current forest land in the South by 2020. Research conducted by SRS scientist **David Wear** suggests that the total change in forest land is dependent on whether rural areas in the South experience increases in forest land. In the past, shifts in land use from agriculture to forest land have offset the net loss of forest land to urbanization. Although these changes have not been distributed evenly across the region, the overall forest land area has remained relatively stable since the 1930s. Future offsets will depend on prices of timber and agricultural products.

Assessments conducted by Wear examine two scenarios. The base scenario uses population, income, and housing forecasts to provide an estimate of how population and economic growth will drive urban land use if there is no change in timber or agricultural prices. The base scenario predicts a loss of 31 million acres of forest land by 2040. The market scenario shows how the base would be altered by a moderate increase, 0.5 percent per year, in timber prices and no change in agricultural returns. This scenario predicts a similar loss of forest land to urban use, but it also predicts a conversion of marginal, or less productive, agricultural land to forest. This conversion nearly compensates for the loss of forest land, predicting a net loss of 3 million acres.

As in the past, land use changes will not be evenly distributed. The land conversion projected in the market scenario indicates the largest block of potential gain in forest land would be in the western third of the South. Forest loss will be concentrated in the eastern half of the South—the greatest loss will occur in the Southern Appalachian Piedmont.

Shift in Productivity

Climate change will impact forest productivity in several ways. Both ozone and carbon dioxide directly impact trees and forest processes. Ozone levels in the troposphere, the part of the atmosphere closest to land, have increased due to human activities. Ozone is taken up by plants through stomata, the small openings in the leaf through which water and gases pass into and out of the plant. A strong oxidant, ozone directly and immediately damages plant cell membranes. The net effect is a decline in photosynthesis, the process that converts the energy in sunlight to chemical forms of energy that can be used by plants. Analyses suggest that ozone levels have decreased production in southern pine plantations by 5 percent.

Elevated levels of carbon dioxide in the atmosphere are having quite a different impact on trees, often referred to as a fertilizing effect. In a 10-year experiment in central North Carolina, trees exposed to continuously elevated concentrations of carbon dioxide had a 20-percent increase in overall growth, compared to untreated trees. Several studies have produced this increased growth response—although the actual responses vary according to the species and the availability of water and nutrients. It is uncertain how long these responses can be sustained, but in the short term, it seems forest productivity is likely to increase over the next 50 years due to the fertilizing effect of atmospheric carbon dioxide. Unfortunately, new research results indicate that increased productivity does not necessarily equate to increased carbon sequestration.

Economic Impacts May Depend on Human Values

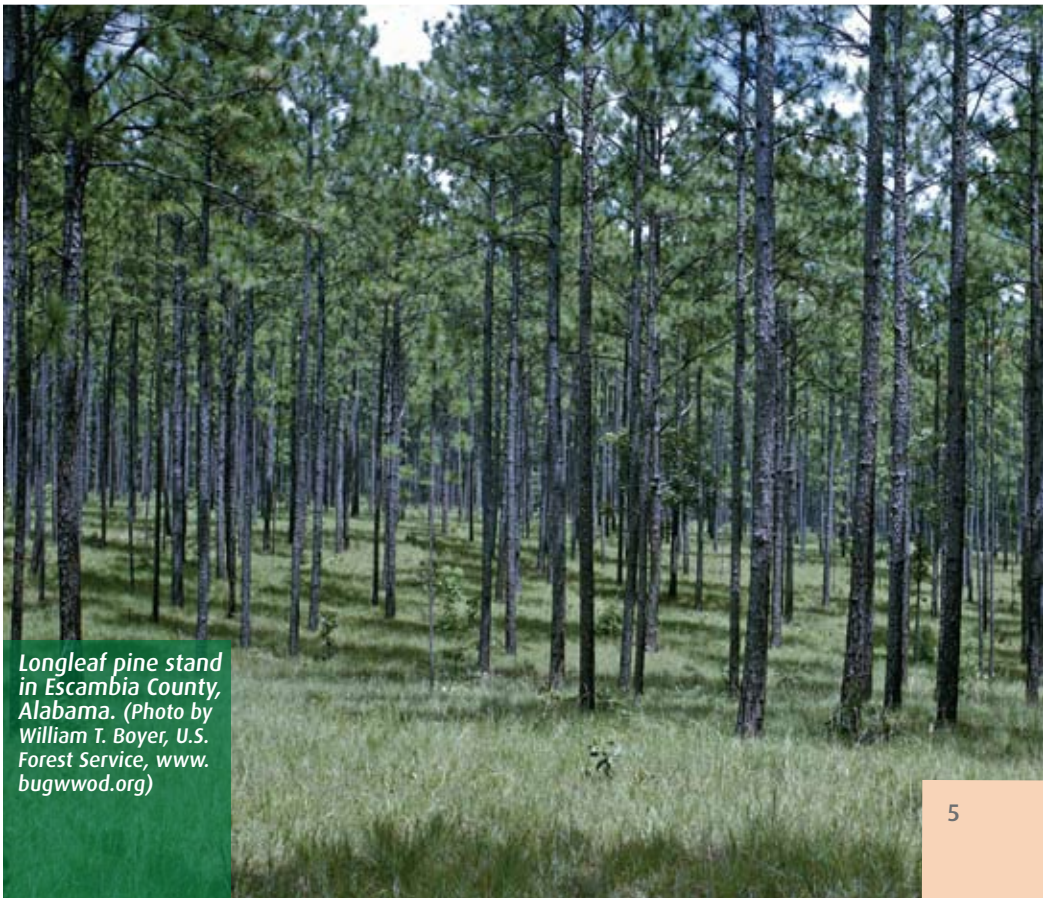
The South has demonstrated a strong advantage in producing a renewable timber resource, but recent changes in timber markets have raised questions about the future. An analysis conducted by SRS scientists Wear and **Jeffrey Prestemon** indicates that concerns about southern timber markets have shifted from a focus on supply issues to a focus on demand issues. The South has supported a more than doubling of timber production over the past 30 years, and forecasting models show the region can easily supply even more timber. The question is whether future demand will rise as fast as the available supply. Evidence does not support continuing strong demand for pulpwood, at least not for paper production. This may be due in part to an increase in the use of recycled fiber in many paper products. Customer demand for engineered wood products is increasing, but so far, rising demand for these products has not been sufficient to offset declines in demand for pulpwood by the paper sector.

A Way of Life

Climate change could impact many of the amenities, goods, and services from forests. Changes in forest species composition, growth, and mortality will alter recreational opportunities, wildlife habitat, and the supply of specific types of wood and products—particularly specialized markets. The majority of plants harvested for medicinal, edible, and floral products require very specific site conditions to grow and reproduce, giving other species that more readily disperse the upper hand. These specialized markets are a significant part of many local economies.

Outdoor recreation will likely be impacted by climate change, particularly in the mountains. Projected increases in per capita income are expected to increase the demand for snow-related recreation. However, fewer cold days and snow events will reduce opportunities to provide cost-effective winter recreation. Summer recreation, on the other hand, is very likely to increase as more "flatlanders" are expected to flock to the mountains seeking refuge from the heat. The biggest single impact to recreation may be to fishing. Warmer water temperatures will cause the disappearance of cold water fish species such as trout. The greatest losses of trout are predicted to occur

"Climate change makes droughts worse, causing worse insect outbreaks and worse fires, which in turn means more smoke and carbon in the atmosphere—and more climate change. This cycle threatens the capacity of our forests to provide all kinds of environmental services that people have come to expect, including clean air and water, habitat for fish and wildlife, and opportunities for hunting, fishing, skiing, and other kinds of outdoor recreation. *—Gail Kimbell, Chief, U.S. Forest Service*



Longleaf pine stand in Escambia County, Alabama. (Photo by William T. Boyer, U.S. Forest Service, www.bugwwod.org)

in the southern mountains where fishing is integral to rural culture and tradition.

What of Their Future?

Climate change and variability have altered and will continue to alter the composition, structure, and processes of forest ecosystems, the amount and quality of forest products and resources, and the social and economic values of southern forests. But humans—through their demands, preferences, choices, policies, and values—can alter the level of climate change and significantly reduce adverse impacts.

While many factors influence climate change, human activities are the dominant force, and are responsible for most of the warming observed over the past 100 years. The largest known contribution comes from the burning of fossil fuels, which releases carbon dioxide into the atmosphere.

For more information:

Steven McNulty at 919–515–9489 or smcnulty@fs.fed.us

David Wear at 919–549–4011 or dwear@fs.fed.us

Jeffrey Prestemon at 919–549–4033 or jprestemon@fs.fed.us

Learning to Adapt

Most actions proposed to deal with global climate change have focused on mitigation, on strategies to reduce the greenhouse gases that contribute to warming. But now many, including Forest Service researchers, are looking at ways to adapt to uncertain future conditions. For managers of natural forested lands, this could mean using silvicultural methods—including prescribed fire—to give species more adapted to drought and higher temperatures the advantage. A recent study by SRS research forester **Martin Spetich** in the Boston Mountains of northern Arkansas offers a prime example.

Spetich and Hong He, associate professor of forestry at the University of Missouri – Columbia, recently completed a study that projected oak decline in the Boston Mountains over a period of 150 years. Using LANDIS, a well-known forest succession and disturbance model, they were able to compare potential oak decline sites under current and historic fire regimes and establish risk ratings for the areas they studied.

"This process represents a further step towards the kind of precision planning and management we'll need to maintain the ecological services forests provide under scenarios of drought, higher temperatures, or other disturbances," says Spetich.

The complex ecosystems of the Boston Mountains have been modified over the last few centuries by both human and natural factors, including drought, fire suppression, and oak decline. Oak decline, which is not really one disease but a response to multiple stressors, has had a severe effect on the forests of Arkansas and Missouri, impacting almost 300,000 acres over the last 8 years. Spetich and He found that oak decline operates over long time scales in association with forest succession—and that white oak survives these stressful conditions better than red oak.

If climate conditions in the Boston Mountains become even more severe, the moister north slopes and coves that have been relatively untouched by oak decline during droughts could be affected in the future, stressing and killing red oaks.

"We've shown that we can explicitly identify areas at high risk for oak decline," says Spetich. "These hot spots could be given high priority in landscape management strategies. In some cases, this would mean using fire at historical levels to get white oak well established before climate impacts."—*ZH*

For more information:

Martin Spetich at 501–623–1180, x105 or mspetich@fs.fed.us

Ramps have been harvested for decades for annual spring festivals in the Southern Appalachians. (Photo by Gary Kauffman, U.S. Forest Service)

THAT CARBON DANCE

by Zoë Hoyle

Carbon—the basic building block of life itself—moves in a cycle through earth, sea, and sky. Along the way, it's taken up and stored—sequestered—for varying periods of time in soils, plants, and oceans. Trees and forests represent major biological "carbon sinks," places where carbon is sequestered.

Planting trees is often suggested as a way to "offset" the increased human contributions to atmospheric CO_2 that have led to global climate change, with some schemes actually tallying how many new trees it would take to offset a year of car emissions. But it's hard to make those calculations accurately because just how much carbon trees sequester—and more importantly, how that might change in response to heightened CO_2—is not precisely known.

Scientists working in the area do know one thing: It's not going to be as simple as "more trees, more carbon sequestered." And there are other, maybe more pressing questions: How will the forests we rely on change in response to climate conditions? Can forest management play a part in adapting forest ecosystems to climate change?

Team leader and research physiologist **Kurt Johnsen** and fellow scientists with the **SRS Southern Institute of Forest Ecosystems Biology Team** have spent decades developing innovative approaches to answering questions like these on study sites across the South, experimenting with methods that range from sophisticated electronics and genetics to getting down in the dirt and digging up roots.

FACE It

"We know for sure that atmospheric carbon dioxide is increasing," says Johnsen on a recent trip to the free-air CO_2 enrichment (FACE) site in the Duke Forest near Durham, NC, where he and SRS research biological scientist **Chris Maier** chart the physiological effects of increased CO_2 on loblolly pine trees. "That's intriguing for those of us interested in forests, because CO_2 is the basis for photosynthesis. The first question we want to address is how these increased levels affect how trees operate."

"Then there's the related question about carbon sequestration and the opportunity to slow down the rate that CO_2 is increasing by managing forests," continues Johnsen. "To be able to answer those questions, we need to be able to quantify how much carbon is sequestered in different parts of the tree, and what happens when atmospheric CO_2 increases." That's where FACE comes in.

From above, the FACE site looks like a circle of silver tubes poking up above a sea of loblolly pines. The tubes release CO_2 over the tops of the trees through computer-controlled valves, the output automatically adjusted to account for the ambient movement of air. Down on the ground, you can see that many of the tree stems are cuffed and wired; tangles of cables crisscross the forest floor among litter baskets and soil probes. The cables connect up to big red tool boxes that carry ACES, a patented system designed by SRS plant physiologist **John Butnor** to measure the carbon coming off tree trunks

Researcher and team leader Kurt Johnsen has spent decades developing innovative approaches to studying forest carbon cycles. (Photo by Chris Maier, U.S. Forest Service)

Observation tower on FACE site in the Duke Forest. (Photo by Rodney Kindlund, U.S. Forest Service)

CARBON DANCE

and soil. There's a constant sound of rushing air on the FACE site; Johnsen and Maier have to raise their voices to be heard.

Pointing to a tree cuff, Johnsen gives a simplified version of what goes on out here. "This cuff is measuring how much CO_2 or carbon is coming off the tree stem. What we're doing here is breaking down the carbon cycle in trees into smaller parts to get a mechanistic understanding of how carbon is cycled through the forest. We're also looking at how fertilization affects growth and carbon sequestration under heightened CO_2."

This brings up the potential importance of loblolly pine in carbon sequestration. Globally, it's the species most widely used for plantation forestry. Because loblolly pine plantations are so extensive and grow so rapidly, they have great potential for sequestering atmospheric carbon. "Loblolly pine plantations are relatively simple ecosystems, and we already know a lot about this species," says Johnsen. "This means we're able to quantify the carbon dynamics for these stands relatively easily, which helps us develop the tools and protocols to measure other types of stands."

Johnsen stresses that results from one site don't easily translate to another. "This is why we study how the different components of the carbon cycle respond to the environment," he says. "The varying responses are then combined to create models to estimate what will happen on other sites. This also provides us the tools to develop forest management to optimize the amount of carbon that's being sequestered in products such as timber—or stored below the ground in root systems."

Belowground, Carbon Banks

The soil at the FACE site in the Duke Forest is very rocky, so it's been almost impossible to measure tree roots using nondestructive probes and ground penetrating radar. Most methods used to analyze carbon storage in taproots—the main roots that usually grow straight down—require digging them up, but researchers are not ready to cut down the pines on the FACE site. Fortunately, a project in the Coastal Plain of South Carolina with forest industry partner MeadWestvaco has provided a timely opportunity to study the role tree taproots play in carbon sequestration.

Named for a nearby town, the Cross Carbon study was set up 4 years ago to look at whether adding the organic matter left after harvesting on a pine plantation could raise soil carbon levels and increase productivity on the wet, sandy soils of the Coastal Plain. When the study started, the trees on the plantation site were at the end of their rotation, so SRS researchers were able to take measurements before and just after harvest. Since it's a pulpwood site, harvest consists of chipping on site for transport to a mill. Typically, the residue—branches and limbs—are pushed aside into large piles. The study looks at whether adding different levels of this organic material back into the soil will cause trees to grow faster and bigger.

It's also been a good opportunity to look at what happens to carbon in root systems.

"Better growth directly relates to carbon sequestration, and not just because of the carbon that's sequestered in tree stems," says Maier. "The faster you grow and harvest trees on this site, the more taproots you leave in the soil. We've come to see the taproots—which can take 10 to 20 years to decompose—as pockets of residual carbon that can provide the added benefit of short-term carbon sequestration to intensively managed pine plantation sites."

To track what happens to carbon as the roots decompose, Maier and Johnsen went in and mapped all the taproots after the stand was cut, marking them with nails so they can be easily relocated using a metal detector. They'll keep sampling the roots over the next decade.

Clonal Advantages

With 21 plots on approximately 15 acres, the Cross Carbon study is one of the largest of its kind, but what makes it even more important is the fact that all the trees planted on the site are clones. Because clones are genetically identical, researchers can be sure that the results they get from adding different levels of organic material are related to the treatments rather than to genetic differences in the trees themselves.

And there's more. There are actually two different loblolly pine tree clones grown on the Cross site, and the difference between them—one is tall and narrow, and carries about half the foliage of the other—may help scientists answer questions about how to adapt forests quickly to changing climatic conditions or establish forests on degraded sites.

"We suspected that the trees with just half the leaf area would grow just as fast as the others, which has been the case so far," says Johnsen. "These trees will be less affected by lack of nutrients, easier to grow in problematic conditions. Knowing more about how individual clones grow and respond to certain conditions will help land managers select trees that will grow better in specific situations."

Johnsen wants to take it even further, towards developing ideotypes—multitrait characterizations of trees—which managers can use to create specific products such as timber, bioenergy stocks, or carbon sequestration benefits—or to restore forests to sites with specific conditions.

"In this case, the tree with the narrow crown and less leaf area is an ideotype that we think may be useful

Pine Clones...

In the plant world, cloning is part of the age-old process humans have used to produce the best plants for food and other products. When you root a cutting, you are essentially creating an identical copy, or clone, of the plant you took the cutting from. The clonal propagation of loblolly pines for large-scale production, however, is not so simple.

For pine cuttings to root, you have to take them from young seedlings, usually about a year old. You can "trick" a pine into staying young by pruning it, but over time it loses the ability to produce cuttings. This method also produces a limited number of seedlings for a limited period of time for any given pine variety.

Another method of producing pine clones involves culturing embryonic pine tissue in the laboratory, allowing embryos to multiply and mature in a process called somatic embryogenesis. Somatic embryos can be produced in much greater quantities than cuttings and stored indefinitely at very low temperatures, so are available in large quantities when needed.

Genome Guided Selection

Tree selection is based on traits that manifest in the mature tree—crown size, growth pattern, or leaf density. Because trees may take decades to mature, selecting for a tree that combines specific traits could conceivably take a lifetime.

Researchers, including **Dana Nelson** and his team at the **SRS Southern Institute for Forest Genetics** (SIFG), hope to improve the ability of managers to select which varieties of a tree—loblolly pine, for example—they will plant based on genetic information. This could prove critical in adapting forests to the rapid alterations that climate change may bring. The first step is to produce maps of pine genomes, then associate genes with specific traits and produce DNA markers which can be used to identify and track individual genes. SIFG researchers have developed over 200 genetic markers for loblolly and related pines—improving genetic maps, allowing comparisons among pine species, and providing the tools for the next generation of tree improvement.—*ZH*

For more information:

Dana Nelson at 228–832–2747, x 201, or dananelson@fs.fed.us

SRS biological scientist Chris Maier shows how data is collected on carbon efflux from tree stems. (Photo by Rodney Kindlund, U.S. Forest Service)

CARBON DANCE

for sites that have less nutrition," says Johnsen. "It might also be useful for short-term biofuels plantations because you could plant the trees close together and cut them in shorter rotations." But it may be the other clone that holds the key to processing wood into biofuels, an alternative that might help reduce the use of carbon-emitting fossil fuels in the not-so-distant future.

Breaking down lignin, the binding agent that holds cells in wood together, is what makes processing wood into the slurry for both pulp and biofuels expensive both financially and ecologically, since the process often involves using toxic chemicals like dioxin. The second clone planted at the Cross Carbon site has a natural mutation in the gene that controls the last step of lignin production. "We think the lignin produced in this tree will be more easily broken down, using less energy to convert it to biofuels," says Johnsen.

Adaptation is Key

"We're a society that relies on forests, and not only for products," says Johnsen. "If forests start changing rapidly, we need to be prepared to do something to keep ecosystems intact—plant different species, for instance. There's a need to develop management systems that can respond fairly rapidly. This is where clonal forestry comes in, making it possible to quickly get a forest planted on a site, even though it may not be the forest you ultimately want."

Coming up with ways to select tree species and varieties that will adapt under rapidly changing conditions led Johnsen back to a long-term experiment in Mississippi and a new collaboration with SRS genetics researchers.

The **Harrison Experimental Forest**, just north of Gulfport, MS, is also home to the **SRS Southern Institute of Forest Genetics** (SIFG), where project leader **Dana Nelson,** who is also project leader of the larger **SRS Forest Genetics and Ecosystems Biology** unit, directs studies that range from sequencing the loblolly pine genome to measuring the response of clonal varieties to different environmental conditions. Experimental plots were established in 1960 on the Harrison to test responses over time of three pine species—longleaf, loblolly, and slash—to four different levels of fertilization put in the second year of the project. The most interesting result is that the one-time fertilization seems to have made all the difference on the gulf coast site, with effects persisting for over 45 years. Katrina turned up another interesting result.

"Along the gulf coast, longleaf pine was largely replaced by loblolly because it was thought to grow faster, and it does in short rotations," says Johnsen. "At the Harrison, we've been able to show that after about 25 years, longleaf catches up with loblolly—and Katrina showed us that longleaf is a lot less vulnerable to hurricane damage. So we know that for that area, longleaf pine will keep carbon out of the atmosphere a lot longer than loblolly pine, especially if hurricanes become more frequent. This is important information for land managers deciding how to replant hurricane-damaged areas."

Johnsen and Maier have teamed up with SIFG researchers to install a new version of the pine studies at Harrison. Before harvesting most of the old study plots, researchers will go in and dig up taproots for analysis, following their decomposition over time. Then they'll replant the plots, partially with seeds collected from the site and partially with genetically improved stock. They want to test whether the improvements in site quality from that one-time fertilization 47 years ago persist into the next generation, and whether trees can be designed to take even better advantage of a relatively simple treatment.

It's about growing trees better for meeting the goals of landowners. "I don't think there will be many cases where people will manage forests just for carbon sequestration," says Johnsen. "But it could definitely provide a benefit—along with ecosystem restoration, recreation, wildlife habitat, and income from timber—to landowners looking for incentives to keep their land in forests."

For more information:

Kurt Johnsen at 919–549–4012 or kjohnsen@fs.fed.us

Chris Maier at 919–549–4072 or cmaier@fs.fed.us

Collaborators include: Duke University, Boston University, the Forest Service Rocky Mountain Research Station, and Colorado State University

SRS researcher John Butnor with the device he developed to take ground penetrating radar (GPR) readings on the forest floor. (Photo by Brian Ward)

New Tools to Measure Forest Carbon Cycling

by Brian Ward

In a small utility closet in his Burlington, VT, office, SRS researcher **John Butnor** unveils a contraption that looks like an off-road scooter with one wheel missing. In fact, the apparatus does contain half a skateboard deck, along with plenty of PVC piping and duct tape. While it doesn't have the sleek look of most scientific equipment, it can, given the right conditions, deliver a remarkably clear picture of the subterranean structure of trees.

Ear to the Ground

Butnor is a researcher with the **SRS Southern Institute of Forest Ecosystems Biology Team** based in Research Triangle Park, NC, which has been refining technologies for research on how forests use and cycle atmospheric carbon.

Carbon has been a hot topic as of late, and one detail very relevant to forest ecosystem research is the way in which trees act as CO_2 storage banks by sequestering it within their physical structures. Calculating the carbon-sequestering ability of trees requires measuring their overall mass, which is relatively easy when it comes to trunks and stems. Easy, when compared to the task of determining the rest of a tree's mass—the subterranean tangle of roots.

That's where Butnor's invention comes in. His "skateboard" is designed to drag a radar antenna along the ground. If you're used to seeing the sweeping radar screens used to scan the sky, this may seem a little strange. Ground Penetrating Radar, or GPR, differs in that, as the name suggests, a radio transducer directs waves into the ground and then "listens" for reflections. GPR has been used in archaeological, military, and civil engineering applications for years, but Butnor's work is somewhat of a departure.

Traditionally, GPR used very long-wavelength, low-frequency signals to penetrate tens of feet into the ground. Resolution was very poor, but it didn't necessarily matter. "If you were using GPR equipment to clear a minefield," says Butnor, "you'd say 'oh, a reflection, I'd better put a flag here.' As opposed to saying 'I want to see what's down there. What's the diameter of this root? How heavy is it?"

To get such hard data, Butnor's system uses a much higher frequency signal to achieve finer resolution. This allows him to map out and measure the size and distribution of roots down to a diameter of a little under a quarter of an inch. Such high-frequency signals can only penetrate a few feet of soil—a perfect fit for this application since that's where the vast majority of roots are located. The single survey wheel on Butnor's skateboard sets off a radar pulse every few hundredths of an inch as it's moved along a number of straight paths through a plot. Afterwards, the data is processed to form a grayscale picture of the roots.

The system still has its limitations. Rocky soil, for instance, tends to "confuse" the radar. A second limitation is logistical: Too many obstacles on the forest floor can be a hindrance when trying to drag such a large object around.

For these reasons, Butnor's GPR system has been most successful in the more controlled, sandy, well-drained soils of southeastern forest sites, where the technology allows researchers to take repeated measurements *in situ*. The more traditional methods of taking soil cores and digging up, drying, and weighing roots are more destructive and don't allow the type of long-term studies the team is doing. "You can get really good information when you dig up roots," says Butnor, "but you can only do it one time."

Sniffing Out the Soil

While Butnor's GPR system helps to analyze the amount of carbon that trees are converting into mass and sequestering away, his Automated Carbon Efflux System (ACES) does the opposite, measuring the CO_2 being emitted from trees through transpiration and other processes.

While the mobile GPR platform looks somewhat odd, ACES looks almost alien. Resembling an electromechanical octopus, it consists of a central "brain" housed in what looks like a large red tool box connected up to 16 sensors designed to measure the CO_2 diffusing from the woody stems of trees or from the soil near their roots.

Butnor designed ACES from the ground up to provide more accurate carbon readings than similar systems of the past. Such systems used closed sampling chambers, which could skew CO_2 readings. In contrast, air in the sampling chambers of the ACES is recycled whenever it isn't being actively sampled.

Butnor and his colleagues have constructed a total of 22 ACES units, which are currently in use at sites all across the country.

For more information:

John Butnor at 802–951–6771, x 1230, or jbutnor@fs.fed.us

Brian Ward is a freelance science writer based in Lebanon, NH.

A Chilling Solution

Kurt Johnsen, team leader of the **SRS Southern Institute of Forest Ecosystems Biology Team** based in Research Triangle Park, NC, is always looking for new ways to measure carbon storage in trees without destroying them. Late last year, along with fellow SRS team members **Chris Maier**, **Felipe Sanchez**, **Peter Anderson**, **John Butnor**, and Richard Waring from Oregon State University, Johnsen published the first proof of concept for a reversible, nondestructive chilling method to study belowground carbon.

It's been estimated that half the carbon cycling through the Earth's systems is tied up in the photosynthetic process of plants. Though reliable data have been developed on the carbon cycling that takes place aboveground in trees, carbon processes belowground have yet to be accurately quantified. Understanding belowground carbon allocation is further stymied by study methods that destroy the tree as well as the soil fungi (mycorrhizae) that live symbiotically among root systems.

"What happens to carbon belowground is somewhat of a black box," says Johnsen. "It's certainly one of the least understood parts of tree physiology. Accurate measurements of belowground carbon allocation are essential for modeling forest productivity and carbon sequestration."

One method that's been used to estimate belowground carbon allocation involves girdling the tree by cutting through the phloem, the thin layer beneath the bark that transports carbohydrates and other products of photosynthesis down towards the roots. Girdling stops the movement of carbon, but does not physically disturb the roots, allowing researchers to study how root-mycorrhizae interactions affect carbon allocation. The problem is that this method kills the tree.

Johnsen and his fellow researchers decided to try chilling the phloem layer to temporarily interrupt the movement of carbohydrates towards the roots. This would allow scientists to study the same trees over time under different conditions. Although the chilling method had been used before on herbaceous plants, Johnsen's experiment was the first test of the method on large trees in the field.

For the experiment, researchers selected 10 loblolly pine trees in a stand that's fertilized annually. They wrapped the stems of the trees in coils of copper tubing, then circulated antifreeze through the tubing to cool it to less than 35 degrees Fahrenheit. They measured the CO_2 released from the soil to determine if carbon movement through the phloem had been reduced, testing the accuracy of their results by comparing them with those from physically girdled trees in both fertilized and unfertilized stands.

"We found that both chilling and girdling quickly reduce the movement of carbon belowground in trees," says Johnsen. "The difference is that once we stopped the chilling, the trees recovered within 12 hours, while the girdled trees died. Using the chilling method, we can study the same trees at various times of the year under a variety of conditions, which allows us to begin to understand belowground processes—and carbon sequestration—more accurately."—*ZH*

For more information:

Kurt Johnsen at 919–549–4270 or kjohnsen@fs.fed.us

Forests and Water Supply

Water yield can be defined as the difference between the amount of water received from rain and that returned to the atmosphere through evaporation from soil and water surfaces and transpiration from plants. The water supply-and-demand model developed by researchers from the **SRS Southern Global Change Team** is designed to take into account how much water is evapotranspired (the combination of evaporation and transpiration) and used by forest ecosystems.

"When it rains over a forest, over half of that water will be moved back into the atmosphere, where it will eventually form clouds and come down as rain somewhere else," says **Steve McNulty**, leader of the climate change team. "The rest ends up in streams or in deep aquifers—water reservoirs underground. Intact forests supply 40 percent of the municipalities in the United States with water, so the role of forests in water supply cannot be overestimated."

Forests ensure water quality by slowing runoff, stabilizing soils, preventing erosion, and filtering out pollutants. According to Forest Service data, over 180 million people nationwide depend on forests for their drinking water. Forests and their water systems also provide habitat for unknown numbers of species of animals, plants, birds, insects, fish, reptiles, amphibians, and other life forms.

Instrumented trees on the FACE site in Duke Forest. (Photo by Rodney Kindlund, U.S. Forest Service)

Carbon Study Sites Span the South

• In 1990, the **SRS Institute of Southern Forests Ecosystem Biology Team** and collaborators from North Carolina State University set up the **SouthEast Tree Research and Education Site** (SETRES) in Scotland County, NC, to begin research on elevated CO_2 and carbon sequestration. Using whole-tree and branch chambers, researchers studied the response of loblolly pine to elevated CO_2 in relation to site conditions, including water and soil nutrients. SRS elevated CO_2 research moved to the Duke University free-air carbon enrichment (FACE) site in 2000.

• Near Bainbridge, GA, on a 10-acre International Paper research site called the "Field of Dreams," SRS researchers are working with Auburn University forestry professor Lisa Samuelson, studying productivity and carbon sequestration in intensively grown loblolly pine. Experiments with irrigation, fertilization, and pest control on improved stock have resulted in the highest documented rates of loblolly pine growth in North America.

• SRS researchers are working with **Southern Region National Forest System** collaborators on a long-term soil productivity site in the **Croatan National Forest** in North Carolina. With help from other units, Station research chemist **Felipe Sanchez** has charted the decay of slash from logging over time. He has also shown that there is a large short-lived "pulse" of soil organic matter after harvest—an important component of carbon sequestration to be factored in when evaluating the productivity of plantation rotations.

• John Seiler, forestry professor and tree physiologist at Virginia Polytechnic Institute and State University, is an important collaborator on research at SETRES and at the Cross Carbon site featured in the story on page 7. Of special interest is the study conducted by Seiler and SRS research biological scientist **Chris Maier** that examined soil respiration in different pine plantations from stand establishment to full rotation age. Conducted in the Piedmont (low-organic matter sites) and on the Coastal Plain (high-organic matter sites), the research showed that although the high-organic matter sites initially lost more carbon through soil respiration, by full rotation age both types of sites had similar carbon losses, presumably because root respiration was the major contributor of carbon.

Other collaborators include: Canadian Forest Service, Duke University, Forest Nutrition Cooperative, Forest Biology Research Cooperative, Brookhaven National Laboratory, College of Charleston, MeadeWestvaco, Oregon State University, Swedish University of Agriculture Sciences, the University of Georgia, University of Idaho, and the USDA Agricultural Research Service, National Soil Dynamics Laboratory.

WE'RE ALL DOWNSTREAM

by Zoë Hoyle

Global warming and climate change are in the news every day now. It may seem natural to tie this summer's drought to Earth's warming, but it's been hot and dry before: Just think of the Dust Bowl years of the 1930s. So is this summer a one-off, or a bitter taste of things to come? Either way it brings up questions. Will there be enough water in the South for our future needs under present climate change scenarios?

Summer in the South, 2007. Temperatures reach the 90s and 100s for weeks on end. There's literally no rain for months. In Georgia, they talk about the kind of drought that only comes once a century as the waters in Lake Lanier drop perilously low. Water restrictions are imposed on the Research Triangle area of North Carolina in September; as the month passes with no rain, restrictions are put in across the State. Crops fail, livestock suffers, river adventures close down; lawns turn brown, and farmers despair.

Researchers with the **SRS Southern Global Change Team** in Raleigh, NC, have focused on this very question since well before climate change became a daily preoccupation. Along with collaborators, team leader **Steve McNulty**, research hydrologist **Ge Sun**, and resource information specialists **Jennifer Moore Myers** and **Erika Cohen** have developed a supply-and-demand modeling framework called the Water Supply Stress Index (WaSSI) that will allow local planners and policymakers to run water supply scenarios at local, regional, and national levels.

Population Pressure

Population is growing faster in the South than anywhere else in the United States, a trend that's expected to continue well into the next century. By 2045, the overall population of the Southern States is expected to almost double that recorded in 1990. The real story is at the individual watershed level, where population change is expected to vary from a 20-percent decrease to a 500-percent increase.

The *Southern Forest Resource Assessment* and other sources project 12 million acres of forested land lost to other land uses by 2020. Almost all global climate change models predict higher temperatures, variable rainfall, and more frequent and intense storms. The combination may bode ill for future water supplies in heavily populated areas.

"As the population in the South continues to grow during the next 20 plus years, surface and groundwater reserves will be reduced in many areas," says McNulty. "Water limitations could occur in new places across this traditionally water rich region."

Tools for modeling water availability at the regional level are not that easy to find, and models developed for both smaller and larger spatial scales have not been designed to work together. To construct WaSSI, SRS researchers combined a hydrologic model with projections from the two major climate change models and with land use and population change projections. They then applied the model to look at eight different scenarios—combinations of climate, land use change, and population—that might take place in the South over the next two decades.

Water yield, the total water that flows out of a particular basin in a specified time, is mainly controlled by climate, land use, and consumption by humans and ecosystems.

When the well's dry, we know the worth of water.

— Benjamin Franklin (1706-1790), Poor Richard's Almanac, *1746*

"We found that the Southern United States has approximately six times more water coming in, on the average, than is being used by people," says McNulty. "You could think of all those rivers flowing into the ocean as excess water."

That's good news overall, but you can have plenty of water flowing through a region and still not have enough in a particular river or watershed to support an intensely

Steve McNulty is the leader of the SRS Southern Global Change Team in Raleigh, NC. (Photo by Rodney Kindlund, U.S. Forest Service)

populated area like the Research Triangle or Atlanta.

"Here in Raleigh we've been having a drought every 2 or 3 years, and we keep adding people. The population for Wake County is supposed to rise by 50 percent between now and 2025," says McNulty. "When we get a dip in our water supply due to drought, it has an enormous impact. All of our scenarios suggest that water yield will increase overall, but in some areas of high population density water demand is already greater than local supply. These shortages will increase and expand in area during the next 20 years."

You Don't Miss Your Water

The greatest area of uncertainty in running water supply scenarios has to do with ground water, more specifically, with knowing how much water is stored in underground aquifers in the Southeast. Aquifers can take centuries, even millennia, to recharge; even years with high rainfall may not be enough to move areas with depleting aquifers out of chronic water stress conditions. And nobody really knows how much water is down there right now.

"There are parts of Texas, for instance, where they receive very little rainfall," says McNulty. "Those are areas that are already heavily dependent on ground water supplies. We know where the Nation's major aquifers are, but we don't know how much water is in them. That puts some areas at severe risk in the future, because it may become very costly to get that water out."

That's why it's important to have locally explicit models. In Texas, ground water is the critical factor. Fluctuations in rainfall from climate change will have a much larger effect in Texas than in the parts of western North Carolina and eastern Tennessee that sometimes get 90 inches of rain a year. Recent findings by the **Southern Global Change Team** show that by the 2040s, areas with limited aquifer reserves and heavy ground-water use will probably begin to run out of ground-water.

"The point of creating scenarios is to give municipal planners and policymakers time to try to prevent severe water shortages in the future," says McNulty. "Now is the time to start measures—whether it's developing networks to move water from other areas, building reservoir systems, or starting water conservation measures."

For more information:

Steve McNulty at 919–515–9489 or smcnulty@fs.fed.us

Scenarios and Climate Change Models

Scenarios are possible alternative futures based on certain conditions. For example, what would happen to water supplies in the South if half the present vegetation disappeared? This isn't likely to happen, but modeling the results of that assumption can help researchers identify possible future trends. Scenarios are not so much forecasts or predictions, but tools to help visualize the influence of certain situations or actions.

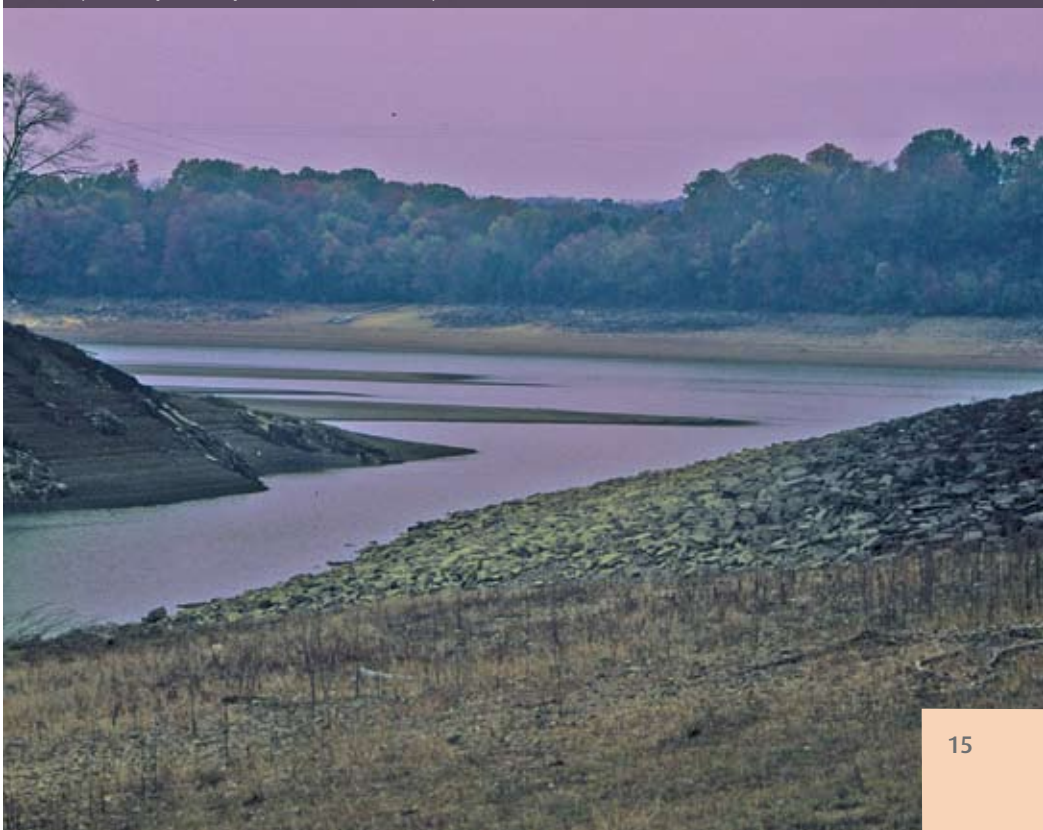
Along with the Intergovernmental Panel on Climate Change, the U.S. Global Change Research Program and others, researchers from the **SRS Global Climate Change Team** run scenarios using two different climate change models—one from the Hadley Centre in the United Kingdom and the other from Canadian Centre for Climate Modeling and Analysis.

The Hadley and Canadian models are in agreement on the general types of changes that will take place over the next century. Climate in general will get warmer, heat indices will rise, and precipitation will be more likely to arrive as intense, heavy storms.

But for the Southeast, there are some critical differences between the two models. For example, the Hadley model suggests wetter weather overall for the Southeast, while the Canadian model suggests drier, with widespread droughts that may transform some forested areas into savannas.

Climate models are far from perfect; there are uncertainties that no one can address at this time, such as exactly how future air pollution and carbon dioxide will affect Earth's energy balances, and how future land covers will interact with the climate systems. This is why scientists use a series of models to cover the potential extremes of climate change.

Water levels on Douglas Lake in East Tennessee fell drastically low during the summer of 2007. (Photo by Zoë Hoyle, U.S. Forest Service)



SRS researcher Devendra Amatya at a gauging station on the Santee Experimental Forest near Charleston, SC. Data from this station and others are used to help predict what will happen to water supplies in the Coastal Plain area under climate change scenarios. (Photo by Wade Spees)

GOING UP TURKEY CREEK

Modeling Water Availability in the Coastal Plain

by John Tibbetts

On a mild, sunny June morning, **Devendra Amatya** stands near a State highway bridge on the bank of Turkey Creek, a gentle blackwater stream in South Carolina's Coastal Plain. The creek winds through the **Santee Experimental Forest**, which is located within the **Francis Marion National Forest** at the headwaters of the east branch of the Cooper River. Only about 15 miles west, the Cooper River flows into Charleston Harbor, the busiest container port in the U.S. Southeast. One moment all is quiet along slow-moving Turkey Creek. Then a deafening convoy of 18-wheeler trucks comes barreling down the highway, rumbling over the bridge and making it tremble.

Development from the Charleston metropolitan area is sprawling closer to the edge of the national forest, one of the last large-scale undeveloped tracts of land in the region. Scientists want to learn how climate change could affect water quality and water availability in the Turkey Creek watershed and other nearby developing areas. First, though, they're going for more basic information, trying to define the "water budget" for the 12,000-acre Turkey Creek drainage area, which is almost entirely located within the national forest.

Standing on the creek bank, Amatya points to a gauging station that provides realtime data on stream flow, water levels, and precipitation to an Internet Web site. "We don't know what's available in this watershed as surface water," says Amatya, a research hydrologist with the **SRS Center for Forested Wetlands** located near Charleston. "We also don't know what's available in ground-water." Long-term monitoring on sites in the national forest—where researchers are also monitoring water quality, testing it for contaminants and dissolved oxygen—will help answer those questions.

General-circulation climate models predict that the Southeast will probably face significant changes in precipitation over the next 50 years. Most climate models show the Southeast becoming wetter, but one model shows it getting drier. Amatya will provide his monitoring data to researchers at the **SRS Southern Global Change Team** led by project leader **Steve McNulty**, who are creating computer models of climate change impacts on forests and water use.

The team, which is led by Steve McNulty and includes research hydrologist **Ge Sun**, has created computer models of 2,100 watershed basins around the United States, addressing potential impacts of climate change, population growth, and land use on forests. "The local watershed information from Turkey Creek will be helpful in validating the regional-scale model of the Southeast that I'm working on," says Sun.

Water When and Where You Want It

Turkey Creek and nearby watersheds are already relatively wet, receiving on average 52 inches of precipitation annually. Even so, "water can be unavailable where you want it and when you want it because of a combination of climate change, population growth, and development," says Amatya. "That's where effective water management comes into play, providing water at the right time and in the right amount."

Localities and water utilities want more information about water availability, but this will increasingly require an understanding of the interplay between climate change and population pressures.

Amatya and SRS colleagues are collaborating with partners from academia, industries, State and Federal agencies, private landowners, and nonprofit organizations to learn more about how water moves throughout the Turkey Creek watershed's low-gradient landscape, which ranges from about 10 to 40 feet above sea level. This information can help scientists predict the impacts of climate change on the watershed's water flow.

"This watershed is becoming a user facility for scientific partners who are interested in understanding various aspects of water quality and availability in the region," says **Carl Trettin**, team leader for researchers at the Center for Forested Wetlands. "What we'll provide is an infrastructure and basic facilities, and encourage partners to come in and participate."

Amatya has established a cost-sharing partnership with the U.S. Geological Survey's Columbia district office to set up and monitor the precipitation-and-flow-gauging station on Turkey Creek. These data are expected to be especially valuable because the creek was previously monitored from 1963 to 1983. By comparing recent and historical data, scientists can learn about the watershed before and after Hurricane Hugo, a category 4 storm that in 1989 destroyed more than 80 percent of

TURKEY CREEK

the national forest's tree canopy. The researchers plan to study how Hugo's destruction of the watershed's tree cover—which changed a mature forest to one made up of younger trees—has affected long-term water availability and flow dynamics in Turkey Creek. Comparing long-term datasets, the scientists can also examine the rain pattern in the watershed since 1983 to estimate whether there has been any change in precipitation.

"This study could help us understand how climate events will affect the forest and the region's water balance in the future," says Amatya.

Water Through Forest

It's a given among researchers that climate change will alter the water patterns of this region over the next decades. SRS scientists and collaborators are developing information on how water moves today through undeveloped forested areas along the South Carolina Coastal Plain to establish a baseline for comparison purposes.

"In the Coastal Plain you don't have the dominant force of topography shaping how water moves downhill, as you do in the hills or mountains," says Trettin. "At first glance, you would not expect to find rapid runoff after heavy rains in the Coastal Plain, but it can happen here. The region has a mixture of soils. Close to the ocean there are sandy soils, which allow precipitation to soak into the ground. But a little farther inland the soil's more often comprised of heavy clay, which doesn't allow much moisture to soak in, so at times we can see runoff rates similar to those in the mountains."

The SRS team plans to study the Turkey Creek watershed as a reference site, comparing it to nearby, geographically similar watersheds that face growing development pressures. As the climate changes in the future, how would the water budget in this reference watershed compare with those of nearby developing watersheds? "If you cut down forests, which are effective water pumps, and build houses in their place," asks Trettin, "how does that affect the water running through that developed system?"

Sea Levels and Ground Water

Within the national forest, only a few hundred yards from Turkey Creek, SRS scientists have installed shallow ground-water wells that go down to 8 feet. With support from the South Carolina Sea Grant Consortium, Timothy J. Callahan, a geologist at the College of Charleston, in collaboration with SRS researchers, has installed an additional series of deep ground-water wells that range from 15 to 130 feet deep.

Monitored continuously, the wells provide data showing how both shallow and deep ground-water supplies respond to various climate events such as droughts and heavy rains.

"In the natural system, how much precipitation is infiltrating into shallow ground water?" Trettin asks. "How much is infiltrating into deeper ground water? And how much is running off the natural areas into creeks? We have little understanding of all that."

Over the next decades, climate change is expected to raise sea level, which would drive freshwater tides farther up coastal rivers, potentially creating new wetlands—and changing ground-water levels in areas like the Turkey Creek watershed. Homes built on land that seems high above sea level today could be more vulnerable to flooding in the future.

The scientists have also installed a weather station, which provides data that can be used to calculate evapotranspiration—the process by which plants pump water into the atmosphere. The researchers can then calculate evapotranspiration from the trees in the surrounding woods. "We're looking at the role of vegetation as a water pump," says Amatya "How water is drawn out of the forest system and pumped back into the atmosphere is part of the water budget."

Evapotranspiration in mature trees can store and release up to 85 percent of the water flow in a southern Coastal Plain forest during a very dry period, but only 50 percent when very wet, says Amatya. As a result, heavy rainfall in a wet period can cause damaging floods because forest trees are already saturated with water.

Models for Watersheds

Amatya plans to use monitoring data from the Turkey Creek watershed to create a hydrological model to describe the local area's "water budget" over time and provide researchers a way to understand today's water flow condition—and estimate impacts of more intense droughts or floods as the climate changes.

"We want to test whether a hydrological model can predict what's happening now," says Amatya. "We'll calibrate the model to what we measure in the watershed."

When the model is calibrated, Amatya will incorporate data from the two major global climate models, which predict contrasting scenarios for the Southeast in the future—one wetter, the other dry—into his hydrological model for the Turkey Creek watershed.

"We can then look at how ground-water and surface-water flows would be affected by either scenario," says Amatya. "For example, isolated wetlands might start disappearing if we see more drying. "

The model for the Turkey Creek watershed will also be useful for understanding its future hydrological response to both climate and development. SRS scientists will use the results of the model to help regional water managers understand the impacts of future withdrawal rates from ground-water and surface-water resources.

"The South Carolina Coastal Plain is a wet, humid region," says Trettin. "But water is not available in a limitless supply. There are going to be changes in the forested communities and water supplies as the climate changes, and we need to understand how these systems function now, to estimate how they will function in the future."

For more information:

Carl Trettin at 843–769–7002 or ctrettin@fs.fed.us

Devendra Amatya at 843–769–7012 or damatya@fs.fed.us

Cooperators include:

Clemson University, College of Charleston, Ducks Unlimited, Inc., Francis Marion National Forest, MeadWestvaco, National Oceanic and Atmospheric Administration, National Council for Air and Stream Improvement, South Carolina Department of Health and Environmental Control, South Carolina Department of Natural Resources, South Carolina Forestry Commission, The Nature Conservancy, U.S. Geological Survey, USDA Natural Resources Conservation Service.

John Tibbetts is a science writer located in Charleston, SC.

SRS researchers and collaborators monitor ground-water and precipitation levels and water quality, testing for contaminants and dissolved oxygen. (Photo by Wade Spees)

A Vulnerable Southeastern Coast

Climate change is already contributing to rising sea levels across the Earth, the result of warmer ocean temperatures and melting glaciers and ice fields. Recent studies show that across the globe, average sea level may rise as much as 21 to 56 inches by the year 2100.

Combined with other effects—hurricanes and storms, erosion, human population growth, and development—rising sea levels will bring definite changes to the southeastern Coastal Plain, impacting most of the human population of the Southeast, as well as terrestrial and aquatic animal and plant populations.

The low elevation marshes and barrier islands of the southeastern Coastal Plain are particularly vulnerable to rising sea levels. Already some gulf coast marshes are submerging because sediment is not accumulating fast enough to keep up with rising sea levels. In some areas, forests will decline due to the intrusion of saltwater, and estuary and aquatic plant communities are threatened by changes in both water salinity and depth.

Coastal managers will need to look at rising sea level effects when planning habitat restoration. City and county development planners should account for sea level rise in coastal development plans, discourage development in coastal hazard areas, enhance shoreline protection, and protect and restore wetlands and forests as natural buffers for the effects of inward moving shorelines.

Adapted from: U.S. Global Change Research Program. 2001. Climate change impacts on the United States. *Cambridge, UK: Cambridge University Press. 612 p.*

TOO WARM FOR TROUT?

by Kim Barto

Can you imagine a future without trout swimming in mountain streams? A hundred years from now, the recreational fishing that many people enjoy in the Southern Appalachians could be a relic of the past.

Two recent studies, carried out in part by SRS scientists, project that rising temperatures from climate change will shrink natural trout habitat in different areas across the country. This research gives a grim prognosis for some species in the warmer climate of the future.

Patricia Flebbe, research biologist at the **SRS Fisheries Team** in Blacksburg, VA, is the lead author of a study which maps out the potential distributions of three trout species in the Southern Appalachians as temperatures increase. **Susan Adams**, research aquatic ecologist with the **SRS Center for Bottomland Hardwoods Research** hydrology team based in Oxford, MS, collaborated with **Forest Service** scientists at the **Rocky Mountain Research Station** to predict changes to the bull trout populations in the Western United States.

Although these projects were conducted independently of each other, their findings fit together well.

According to Flebbe's model, between 53 and 97 percent of wild trout populations in the Southern Appalachians could die out as streams become warmer. Trout are coldwater species that depend on relatively low stream temperatures to survive.

"Trout are already at the southern limit of their range," Flebbe says. "Suitable habitat area will shrink and become much more fragmented as the climate becomes increasingly warm."

Flebbe, with fellow researchers Laura Roghair from the Virginia Tech Conservation Management Institute and former SRS employee **Jennifer Bruggink**, first examined the current distributions of the native brook trout and the introduced rainbow and brown trout in the Southern Appalachians. They developed a regional map of wild trout habitat based on stream samples, expert knowledge, and suitable land cover.

Their model substitutes elevation and latitude for temperature, creating a more spatially explicit way to predict habitat loss over the next century. The resulting paper was published in the *Transactions of the American Fisheries Society* in 2006.

The problem of habitat fragmentation will continue to worsen as temperatures rise. Disturbances such as changes in land cover, road building, increased angling, and other factors already limit the distribution of trout in this region. Flebbe predicts that the fish will eventually exist only in "islands" at the highest elevations, leaving them especially vulnerable to dying out.

"Small populations in isolated patches can easily be lost," Flebbe says. "In a warmer climate, local extinctions may become irreversible."

The extent of these extinctions will depend on how much the stream temperatures actually rise in the Southeast. Flebbe, Roghair, and Bruggink used two different global circulation models to predict habitat loss.

Using the Hadley Centre model, the team determined that 53 percent of trout habitat could be lost by the year 2100. Using the more extreme Canadian Centre model, they projected a loss of 97 percent.

Flebbe's model does not address what people could do to mitigate the effects of climate change, but it is likely that humans will have to manipulate fish species in order to provide the fishing experience. State agencies already raise millions of trout and release them into streams for people to catch.

"We have a long history of altering aquatic communities by stocking game fish and introducing other species," Flebbe says, adding a word of caution, "However, stocked trout do not function in the same way within the ecosystem."

Still, uncertainty remains about how trout will react to the warming climate.

"There's a real argument about whether fish can adapt to climate change quickly," Flebbe says. "There are potential issues related to changing physiology. The next step will be looking at the fish and how they respond to temperature."

Predicting the Bull Trout's Future

While Flebbe modeled projections for three species of trout, including two nonnative varieties, Adams' research focused on the bull trout in the Interior Columbia River Basin. Bull trout are native to five States in that region and are considered a threatened species under the U.S. Endangered Species Act.

"Bull trout may be especially vulnerable to climate change, since they require cold water for spawning and early rearing," Adams says. "Some populations appear to face higher risks than others."

Adams and her fellow researchers explored the implications of climate change over the next half-century by modeling the species' response to three levels of projected temperature increases.

"We concluded that warming over the range modeled could result in a loss of 18 to 92 percent of stream area cool enough to support bull trout reproduction," Adams says. "Perhaps more importantly, the models predicted a 27- to 99-percent loss in the number of large habitat patches that are critical to population persistence."

The model predicts how climate warming will raise the lower distribution limits of bull trout population, as well as how the increasing fragmentation of the habitat with rising temperatures will accelerate the loss of bull trout.

Adams is the third author of the paper, recently accepted by the *Transactions of the American Fisheries Society*. She collaborated with a number of scientists from the Rocky Mountain Research Station: **Bruce Rieman**, **Daniel Issak**, **Dona Horan**, **David Nagel**, **Charles Luce**, and **Deborah Myers**.

Earlier research conducted by Adams, published in 1997, confirmed a correlation between summer water temperatures and downstream distribution limits of small bull trout in Idaho without explicitly addressing climate change.

"In the recent paper, we used bull trout distribution data and modeling to examine the relationship between bull trout distributions and air temperatures over a large area," Adams says.

"We also added a second modeling component to look at how the interaction of shrinking habitat and increased fragmentation would interact. The results illustrate that climate warming could pose a substantial threat to the persistence of bull trout throughout much of the basin."

The researchers also found the suggestion of a synergy between the effects of stream warming and invasion by nonnative brook trout, but say the connections have been hard to determine concretely.

Speaking of Flebbe's research, Adams says, "The two papers complement each other in a very important way, because although they are completely independent analyses, both show very similar predictions for losses of habitable stream area for trout in different parts of the country."

For more information:

Patricia Flebbe at 540–231–7202 or pflebbe@fs.fed.us

Susan Adams at 662–234–2744, ext. 267 or sadams01@fs.fed.us

Kim Barto is a freelance writer based in Asheville, NC.

Studies by SRS researchers Pat Flebbe and Susie Adams project that rising temperatures will shrink habitat for native trout in different areas across the United States. *(Photo by Pat Flebbe, U.S. Forest Service)*

MUSSELS: DO NOT DISTURB!

by Claire Payne

Rising temperatures from climate change could mean disturbing times ahead for freshwater mussels in the South. **Wendell Haag**, fisheries research biologist with the hydrology team of the **SRS Center for Bottomland Hardwoods Research** based in Oxford, MS, is refining a method based on mussel shell "rings" which will help determine the effects of disturbance and changing environmental conditions on these bellwether species.

The North America mussel fauna is the most diverse on Earth, but due to a variety of impacts to streams, mussels are among the world's most endangered organisms. As filter feeders, mussels have an important influence on water quality, and the loss of this function in a watershed represents a significant loss of ecological integrity. Haag is the 2007 recipient of the Forest Service Chief's Early Career Scientist Award, recognizing his highly productive research program on freshwater mussels and other aquatic organisms.

It has long been known that mussel shells contain rings similar to tree rings, but until recently, scientists were unsure just how often these rings were formed, limiting the extent to which shell rings could be interpreted. Haag, along with biological science technician **Amy Commens-Carson**, recently completed a multiyear study on the formation of rings in mussel shells. This research, soon to be published in the *Canadian Journal of Fisheries and Aquatic Sciences*, showed that, similar to trees, mussels produce a shell ring each year as the animal grows. The research also showed that mussels are highly sensitive to disturbance.

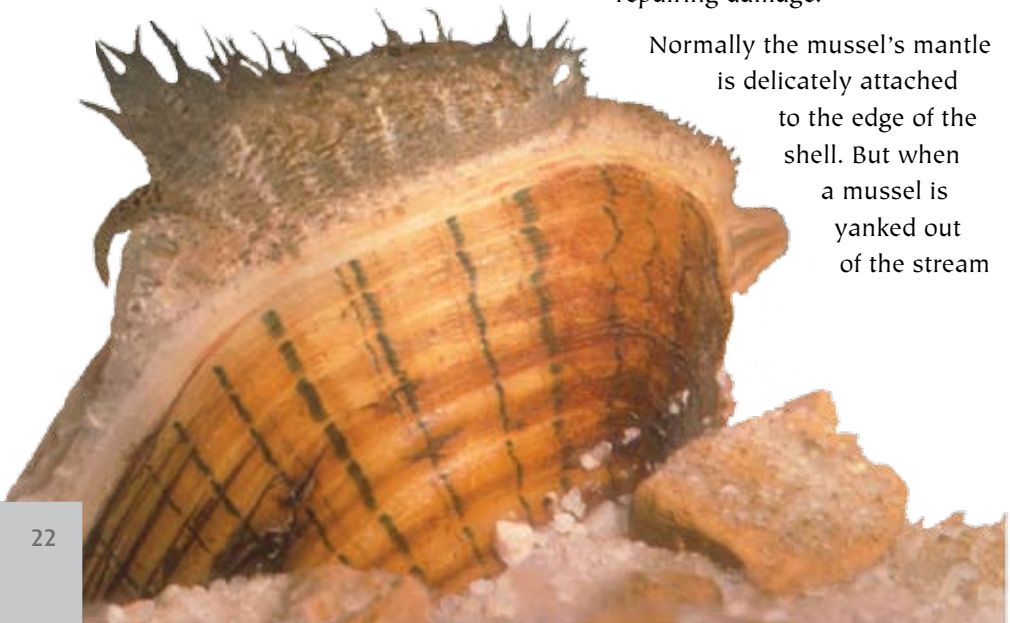
Mussels are renowned for their sensitivity to environmental conditions. Living most of its life burrowed in a stream bed, a mussel doesn't want to be disturbed. During warm weather, the mantle, a thin membrane that encloses the mussel's body, lays down new shell material, increasing the size of the shell and repairing damage.

Normally the mussel's mantle is delicately attached to the edge of the shell. But when a mussel is yanked out of the stream bed—say, by a biologist, a hungry muskrat, or a flood—the mussel clamps its shell shut, retracting the mantle from the edge of the shell. If the mussel survives the encounter and opens again, the mantle doesn't reestablish connection with the shell edge at exactly the same place as it was before being disturbed. This slight misalignment results in the production of a disturbance ring that is often readily distinguishable from annual growth rings.

Because some mussels can live more than 100 years, their shells provide a long-term record of stream and climatic conditions that can now be interpreted using Haag and Commens-Carsons' research findings. Annual variations in growth due to changes in temperature, rainfall, and other factors can be examined by looking at the amount of shell produced between annual growth rings. Furthermore, the occurrence of disturbance rings can provide evidence of floods, drought, or other past environmental events.

In collaboration with researchers at the University of Alabama, Haag is now using shell rings to reconstruct past growth histories of mussels and to assess recent changes in hydrologic variables such as flood and drought periodicity. "Mussel shells hold a wealth of information about the environment," Haag says. "The growth histories recorded in these shells can help us understand past changes in rivers and lakes, as well as predict future effects of climate change on freshwater ecosystems."

Fine-lined pocketbook (Hamiota altilis). *(Photo by Wendell Haag, U.S. Forest Service)*



For more information:

Wendell Haag at 662–234–2744, x 245, or whaag@fs.fed.us

FROGLOGGING IN EAST TEXAS

by Zoë Hoyle

The decline of frog populations across the world has received a lot of attention in the last few years because of the key role frogs play in aquatic ecosystems as both predator and prey. Frogs and other amphibians, with their permeable skin and unshelled eggs, can also be seen as indicator species—canaries in nature's coal mine—for the health of aquatic ecosystems. So far, no single cause has been found for declines in frog populations, though chemicals, disease, and loss of habitat have been identified as possible causes.

Changing weather patterns from global climate change could also be a contributing factor, particularly for frog species using ephemeral water sources. In eastern Texas, some frog species rely on ephemeral sources—sometimes literally a rain puddle—while others rely on permanent ponds.

"It's widely known that the breeding activity of amphibians like frogs is closely tied to weather," says **Dan Saenz**, SRS research wildlife biologist. "However, the specifics of these relationships have barely been explored."

Saenz, along with other scientists from the Nacogdoches, TX, team of the **SRS Southern Pine Ecology and Management** group, is currently studying the effects of rainfall and temperature on the breeding activities of 13 different species of frogs in eastern Texas. Information from the research will make it possible to predict potential effects of a changing climate on frog populations.

"There's a particularly high level of diversity in frog species in eastern Texas," says Saenz. "There's also a lot of seasonal variation in temperature and rainfall, so we suspected that weather might be a major factor influencing breeding activity in frogs."

Gulf coast toad (Bufo valliceps). *(Photo by Daniel Saenz, U.S. Forest Service)*

Frogs call at night to advertise for mates. To study breeding activity in relation to weather, Saenz and fellow researchers used "frogloggers" to record calls at eight different ponds every night for 2 years. Additional dataloggers recorded hourly air temperature and daily rainfall for each site.

After identifying calls from the tapes and relating them to weather data, the researchers were able to map out 5 different breeding patterns among the13 frog species that vary from total independence from local weather patterns to dependence on specific rainfall patterns in specific temperature ranges.

"Our research has shown how frog breeding activity is related to rainfall and temperature," says Saenz. "A prolonged change in the weather will have different effects on different species—some negative, others positive or neutral. We don't know how this will affect the diversity of frog species, but our research has given us a good foundation to begin making predictions."

For more information:

Dan Saenz at 936–569–7981 or dsaenz@fs.fed.us

HEMLOCKS DECLINING FAST

Eastern hemlock is a keystone species in the streamside forests of the Southern Appalachian region. Its shade is key in maintaining the cool water temperatures required by trout and other aquatic organisms. Hemlock branches shelter nesting songbirds, many of which are neotropical migratory species already in decline.

Around 2004, eastern hemlocks in the Southern Appalachians began showing signs of infestation by the hemlock woolly adelgid, a tiny nonnative insect which has spread steadily south since it was introduced into the Northeast area in the 1950s. Once a hemlock is infested, it generally dies within 10 years, but hemlocks in the Southern Appalachians are dying much faster, with untreated trees dying within 3 to 5 years. Warming temperatures don't help.

"Really cold winters, even cold snaps, will slow down the hemlock woolly adelgid," says **Jim Vose**, project leader of the **SRS Forest Watershed Science** unit. "Unfortunately, we have not had those conditions in the Southern Appalachians for the past several winters. The warm weather has been ideal for the adelgids to reproduce and spread."

Water Flow and Temperature

In July 2007, Vose and ecologist **Chelcy Ford** published a study that provided the first estimates on the impact the loss of eastern hemlock will have on the water dynamics of the Southern Appalachian mountains. The data came from experiments the researchers are conducting along the streams at the **SRS Coweeta Hydrologic Laboratory** in Otto, NC, where hemlocks are dying rapidly.

To estimate the impact the loss of hemlocks will have on the water balance, the researchers measured transpiration rates—the rates at which trees return water to the atmosphere—for hemlocks of different sizes over a period of 2 years. "We found substantial rates of transpiration for individual hemlocks," says Ford. "Some of the larger trees transpired as much as 49 gallons of water a day."

The researchers predict that as hemlocks die, forest transpiration could decrease as much as 30 percent in the winter and spring. The loss of the trees' transpiration capacity could mean greater levels of moisture in the soil. Stream flow could increase, saturating streamside riparian zones. The loss of canopy could also change the temperature of streams; it's been estimated that hemlock shade cools some streams by as much as 9 degrees Fahrenheit.

"We're at the point where rising stream temperature could impact trout populations," says Vose. "The shade provided by hemlock helps keep the environment cool enough for trout to survive."

At Coweeta, researchers have already started studies on how to mitigate the loss of hemlock by planting other species—among these, the American chestnut and eastern white pine, but the loss of eastern hemlock will profoundly change southern forests and the groups of species they shelter.

"It's unlikely that any other evergreen native to the Southern Appalachians will fill the role of eastern hemlock," says Ford. —*ZH*

For more information:

Chelcy Ford at 828-524-2128 x 118 or crford@fs.fed.us

Jim Vose at 828-524-2128 x 114 or jvose@fs.fed.us

Hemlock woolly adelgid infestation. (Photo by Connecticutt Agricultural Experiment Station, www.bugwood.org)

HIGH-LEVEL PROBLEMS FOR SONGBIRDS

In the Southern Appalachians there's been a substantial decline in eastern hemlock due to an exotic insect pest, the hemlock woolly adelgid. The loss of hemlock will bring changes in forest composition and structure that may affect the species composition, densities, and nesting success of high-elevation bird communities—especially when combined with the continuing effects of acid deposition.

Acid deposition—more familiarly known as acid rain—occurs when sulfur and nitrogen compounds from fossil fuel combustion combine in the atmosphere with water. Though the Clean Air Act reduced the emissions that cause acid rain, it's still a problem in the high-elevation forests of the Southern Appalachians.

Though much is unknown about how high-elevation ecosystems are affected by continuing acid rain, ecologists have started to suspect that high levels of acid deposition, which leach calcium from the soil, may be one of the causes for unexplained population declines in neotropical migratory birds, especially high-elevation bird species.

Female songbirds need large amounts of calcium to produce eggs. Birds get some of their calcium from insects and worms, but mostly from snail shells, which may be in short supply when calcium is leached from the soil.

When it comes to studying birds, **Kay Franzreb**, SRS research wildlife biologist, has always been in the thick of things—studying forest birds in the Southwest, scrub-jays in Florida, red-cockaded woodpeckers in South Carolina, and neotropical migratory birds in southeastern forests.

Impacts of Hemlock Loss

In 2007, Franzreb, with University of Tennessee collaborator David Buehler, began a field study to assess the possible impact of hemlock loss on birds in the Southern Appalachian Mountains. The researchers already have data on the nesting success and provisioning rates of these species. They will revisit the areas where that data was collected to determine the extent of the hemlock loss and how this loss has affected the bird community by measuring avian densities, nest success, parental provisioning rates, and vegetative structure and composition. Reproductive success of three target species will be monitored: dark-eyed junco, blue-headed vireo, and black-throated blue warbler.

Once the results are in, they hope to use the data to develop landscape-based models that can predict the effects of hemlock loss on bird communities in the Southern Appalachians.

Snail Shells and Nesting Success

In 2006, with North Carolina State University collaborators Rebecca Hylton and Ted R. Simons, Franzreb began a study on the effects of acid deposition and calcium depletion on high-elevation songbird and snail populations in the Great Smoky Mountains National Park. The project focuses on dark-eyed juncos and on six species of snails.

For the study, Franzreb and collaborators are surveying land snail populations across a gradient of low-to-high acid deposition in sites within the national park.

They're also examining museum specimens collected from the area to see if snail shell size, thickness, and calcium content have changed over time.

The information on snails will then be compared to data from the same time frame and location on the nesting success of juncos and the calcium content of their eggs. Blood from nesting juncos has already been analyzed for both calcium and mercury (a chemical pollutant that accumulates in living tissues) levels. The first year of data collection for the project has been completed, with researchers anticipating at least two more years of field work.

"Once we've established this study on sites in the park, we'll expand the research to nearby high-elevation sites on national forest lands," says Franzreb. "If we can better understand the connections between air pollution and the ecology of songbirds and snail populations in the Southern Appalachians, we can provide better recommendations for conservation and management." —*ZH*

For more information:

Kay Franzreb at 865–974–0932 or kfranzreb@fs.fed.us

Black-throated blue warbler. (Photo courtesy U.S. Fish and Wildlife Service)

Pacific Northwest Research Station researcher Ron Neilson's weather models predict more intense wildfires for some parts of the South.
(Photo courtesy National Interagency Fire Center Archive, www.bugwood.org)

TURNING UP THE HEAT

On a Bubbling Cauldron of Forest Threats

by Carol Whitlock

Wildfires, insect invasions, diseases, and nonnative invasive plants are not new to the southern landscape. Some of these forest "threats" actually play a crucial role in the well-being of ecological communities; for example, the original Coastal Plain forest once consisted of longleaf pines, wiregrass, and red-cockaded woodpeckers—all dependent on periodic wildfires.

Some threats that have always been part of the landscape, such as southern pine beetles, rarely reach epidemic levels without the help of unusual disturbances or management practices—in the case of southern pine beetles, periodic dry spells or overcrowded pine plantations.

Still other threats were not an original part of the landscape but have been in the South so long that they'd be missed if they suddenly disappeared. Examples are mimosa and wisteria, two of the most destructive nonnative plants in the region which some would argue are as much a part of the southern culture as grits and red-eye gravy.

Global Change Recipe Calls for Adding Heat ...

The August 2007 online issue of the journal *Nature* reported predictions that the Earth will become more than 6 degrees Fahrenheit warmer by the end of this century—and that every degree of temperature increase will shift ecological zones by about 55 miles. If these predictions prove true, our children could see palm trees as far north as Washington, DC, and our grandchildren will most certainly see them in New York.

The implications of this shift for forest management in the South would be profound, especially in the context of threats. According to the same issue of *Nature*, the plants and animals that survive will be those that can colonize new territory or can adapt their biological functions and mating behaviors to seasonal changes. Within any ecological community, rather than a coordinated northward shift of all species, some will opt for colonizing while others will adapt to the new conditions or die out. Complicating the picture further will be the effects of wildfire and the addition of new species, either those colonizing from further south or those introduced from other parts of the world.

Sudden oak death in California ... will it take hold in the South? Mountain pine beetles in the West ... if warmer temperatures allow them to jump the Rockies, what's to stop them from moving into the South? Cogon grass ... how bad will it get? Fire ants ... are they on the march to the Appalachians? Southern pine beetles ... the South's "gift" to higher elevations and northern climates?

Ron Neilson, a research bioclimatologist with the **Pacific Northwest Research Station**, has been studying weather systems to understand how a warming climate might affect the size and destructiveness of wildfires in various parts of the world. From one season to the next, high and low pressure systems tend to migrate and form into cells as different parts of the Earth receive varying degrees of sunlight. These cells have variations within their boundaries; their cores are subject to greater evaporation and are, therefore, drier, while their outer edges have significantly more rainfall.

Initially, a warmer climate should increase evaporation and produce more rainfall in some areas. Increased rainfall stimulates growth of trees and other vegetation, eventually resulting in more moisture being drawn out of the soil in which they grow. With continued warming, the edges of weather cells move outward, expanding the drier core and parching the newly greened vegetation, causing it to turn brown and become fuel for wildfires.

Neilson's models show that the South is of particular concern for two reasons. First is its location in the Bermuda cell, which will divert rainfall to other U.S. regions and Canada when warming causes it to expand. Secondly, once wildfires get started, they will spread easily over many areas of the South, whose topography and climate are less variable than other regions. As an example, Neilson points to the Georgia-Florida border where two fires, one started in the Okefenokee Swamp, burned an area the size of Rhode Island.

And Then Stirring in New Ingredients ...

Because of their mobility, reproductive success, and short life cycles, invasive organisms can wreak havoc in forest environments, especially those that have already been subjected to fire, drought, and other disturbances.

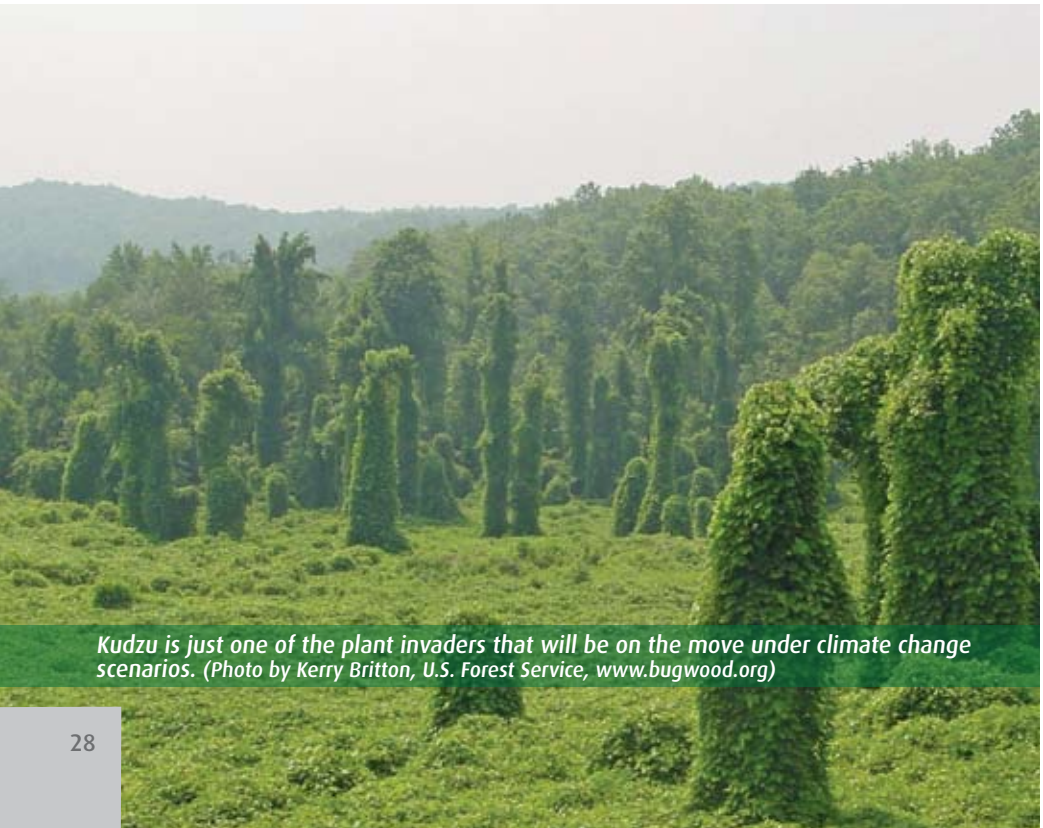
Turning Up the Heat

Native insects and diseases usually attack in cycles followed by periods of relative inactivity. However, recent studies show that for some like the southern pine beetle, the periods of attack are becoming continuous. This phenomenon is most common in environments where the periods between dry spells are compressing, which is predicted to occur more often as climates warm. In addition to invasive populations increasing under warmer and drier conditions, their plant hosts often become more susceptible to attack as their internal chemistry changes in response to climate variations.

Nonnative insects, diseases, and plants present additional challenges, partly because they lack the predators that kept them in check back in their native environments. Whether global warming will increase or decrease invasive organisms is a question that currently has as many answers as species studied. To provide a clearer understanding **Qinfeng Guo**, research ecologist at the **SRS Eastern Forest Environmental Threat Assessment Center** in Asheville, NC, has begun to study the likely effects of global warming on nonnative invasives using a combination of remote sensing, data mapping tools, and mathematical modeling. His goal is to identify the factors that control distribution and population growth of invasives by comparing their native and introduced ranges.

Guo's early research included work on sudden oak death, a nonnative pathogen caused by *Phytophthora ramorum*, introduced in shipments of rhododendron and other nursery plants and which has killed many trees in the Pacific Northwest. He and his cooperators examined five models, all predicting different levels of risk for spread to other regions, and then developed predictions based on where the models were in agreement. According to the consensus predictions, if sudden oak death escapes from the Pacific Northwest, it could move eastward to 9 of the 13 Southern States (Virginia, North and South Carolina, Georgia, Kentucky, Tennessee, Alabama, Arkansas, and Oklahoma).

In the area of nonnative invasive plants, Guo and his cooperators are mapping 20 of the most dominant species from Asia and another 20 North American species introduced into Asia. In addition to monitoring the differences in native and introduced ranges when subjected to climate change over the years, the researchers will collect information on the species' genetic and physical characteristics, distribution patterns, and rates of invasions. The results of this study will help in predicting how global warming will affect the incidence and success of future invasions and in coping with their effects.



Kudzu is just one of the plant invaders that will be on the move under climate change scenarios. (Photo by Kerry Britton, U.S. Forest Service, www.bugwood.org)

New Recipes Needed for Forest Management

Threat assessment center director **Danny Lee** says that Guo's work on invasive organisms is part of a larger effort to evaluate and guard against synergistic and antagonistic threats throughout the Eastern United States. "Our center was established to apply rigorous scientific methods in anticipating future threats and then to supply the tools necessary for making wise decisions and implementing those decisions on public and private lands," says Lee. "Understanding both the vulnerabilities of forest ecosystems and the potential of forest threats to take advantage of those vulnerabilities will be critical to the success of future forest management."

Lee's approach is in line with Neilson's belief that global change places us in a new environment where the future will no longer echo the past: "Historically the goal of foresters has been to manage for the status quo. In this new environment, we no longer will have the luxury of trying to maintain species but will have to look beyond species to the functions they serve within a forest ecosystem. The new challenge for the natural resource community will be to manage for change."

For more information:

Ron Neilson at 541–750–7303 or rneilson@fs.fed.us

Qinfeng Guo at 828–257–4246 or qguo@fs.fed.us

Danny Lee at 828–257–4854 or dclee@fs.fed.us

SNAPSHOT FROM THE FIELD

A Director Undaunted by Threats

by Perdita B. Spriggs

Danny Lee. (Photo by Rodney Kindlund, U.S. Forest Service)

Eastern forests are vulnerable to stresses from insects and disease, wildland loss, invasive species, uncharacteristic fire, and climate change. As new threats emerge and old threats resurface, the **Eastern Forest Environmental Threat Assessment Center** (EFETAC) is uniquely poised as an interdisciplinary resource to actively develop the new technology and tools needed to anticipate and respond to eastern forest threats as they arise.

Established in 2005, EFETAC is a joint effort of the Forest Service's three major branches: **Research and Development**, the **National Forest System**, and **State and Private Forestry**. Director **Danny C. Lee** has an exciting and innovative vision for the center headquartered in Asheville, NC. "The center addresses a variety of complex issues that demand cross-disciplinary integration, collaboration, and creativity," says Lee. "Our work complements ongoing efforts within and outside the Forest Service, and builds on a wealth of existing information."

EFETAC is busy developing new projects, expanding partnerships, and exploring cutting-edge technology. With 2 years behind him, Lee reflects on his growing team, his commitment to partnerships, and his vision for the future.

How has the center grown?

When I arrived in July 2005, there were no other center employees, but I did have the EFETAC charter explaining our purpose. So, I began planning how to build the program, allocate funding, and establish a core team. Early on, I asked the University of Georgia to help develop our Web page, and, thus, jump-started our science communication efforts.

I envisioned a core staff that would include a couple of senior scientists, each skilled in remote sensing and landscape analysis or having specialized knowledge of the primary threats affecting eastern forests. I also wanted a senior communications specialist to lead technology transfer efforts. We completed staffing earlier this year.

Cooperative agreements are extremely important to our program. The idea is to have certain types of in-house capabilities while maintaining the flexibility to bring in additional expertise and resources to tackle specific problems.

How did the recent reorganization of SRS impact the center?

The reorganization combined EFETAC with two existing research work units—the **Southern Global Change Program** in Raleigh, NC, and **Forest Health Monitoring** in Research Triangle Park, NC. Both teams already have solid, existing programs that can be woven into the center's mission. Ironically, these were the first two units I visited to discuss collaborative research opportunities, so it was a good fit. The immediate effect was to increase the center's intellectual, partnership, and resource capacity and improve opportunities for joint research. Essentially, the center grew overnight. We're definitely making progress in the transition from three separate units to one consolidated unit.

What major projects have you initiated?

Regarding threat assessment, the center is collaborating on several notable projects. One is with the NASA Stennis Space Center in Mississippi to identify remote sensing and geospatial technologies that can provide early detection of forest threats. We are exploring several components of early warning systems through partnerships with NASA and with the Oak Ridge National Laboratory, other Forest Service technology units, and the University of North Carolina–Asheville's National Environmental Modeling and Analysis Center (NEMAC).

Emerald Ash Borer. (Photo by David Cappaert, Michigan State University, www.bugwood.org)

Snapshot...

Our partnership with NEMAC will ensure EFETAC is at the forefront of information management in the threats arena. NEMAC brings tremendous expertise in working with large volumes of data and complex information systems. They're helping us to advance our Web technology, especially through developing high speed access to models and databases.

We are also making strides in quantifying the risk posed by invasive species and developing knowledge and tools to help manage these threats. From the science delivery standpoint, we are working to support strategic planning at the regional, national, and international levels by providing new tools and data for comparative risk assessments. We are also partnering with the Southern Group of State Foresters and others to understand the consequences of urbanization, fragmentation, and parcellation of southern forests.

What is your vision for the future?

I envision the center tackling specific issues that involve interactions on a variety of scales and multiple sources of threats. We will focus on a whole complex of threats and how they play out across the larger landscape. We also will continue to enhance our role as a synthesizer of information. Additionally, I would like us to generate policy-relevant research that helps people understand the implications of various land use and management choices.

We're also going to continue asking for input from our stakeholders, keeping our finger on the pulse of the threats community, and sharing useful tools and information.

EFETAC Adds New Scientists

The **SRS Eastern Forest Environmental Threat Assessment Center** (EFETAC) has added four new scientists:

William H. Hargrove

William H. Hargrove joined EFETAC in October 2006 as an ecologist. His current research focuses on designing a national early warning system using satellite imagery that will examine the lower 48 United States at 500m resolution every 8 days to locate potential forest threats. Hargrove began postdoctoral work with the Oak Ridge National Laboratory (ORNL) in 1990 and became an ORNL subcontractor in 1993. He joined the ORNL staff in 2000, with his latest position being in the Environmental Sciences Division's senior research staff. Most recently, Hargrove helped design the National Ecological Observatory Network, produced a set of national wildfire biophysical settings regions for the LANDFIRE project, mapped the risk of sudden oak death spread, and developed the first quantitative global ecoregion

William H. Hargrove

maps in coordination with The Nature Conservancy. He has also developed a practical map analysis tool to predict and map corridors used by wildlife and developed EMBYR, a probabilistic wildfire model to investigate the effects of landscape-level fires. Hargrove received a Ph.D. in ecology from the University of Georgia in 1988.

Qinfeng Guo

Qinfeng Guo joined EFETAC in 2006 as a research ecologist and is currently conducting collaborative research using plant traits in life history and genetics to predict invasiveness of introduced species, and using life history and distribution information from both native and exotic habitats to simulate/predict the spread of invasive species under various climatic scenarios. Guo worked at the University of Nebraska–Lincoln, the University of Arizona, and the University of Tokyo before joining the U.S. Geological Survey in 2001. His work has included desert/chaparral/grassland plant community ecology, simulations of climatic effects on linear forests in agroecosystem, biogeography (disjunct plants between Eastern Asia and North America), and biological invasions. Guo's research interests include plant community ecology, biodiversity, biological invasions, plant-animal cosuccession, community/ecosystem self-organization, and biogeography. A native of Chengde, Hebei, China, Guo received a Ph.D. in biology (ecology) from the University of New Mexico in 1994.

Stephen Creed

Stephen Creed joined EFETAC in January 2007 as a GIS specialist and is applying geotechnologies with other unit scientists to develop an early warning system for detecting natural and human forest threats. Creed joined the Forest Service in January 2005 as part of the **Southwestern Regional Office's** GIS unit in Albuquerque, NM, where he managed aerial photography and photogrammetric mapping projects for fire and recreation, as well as conducting GIS training courses for resource staff throughout the region. From 1999 to 2005, Creed worked as a geographer for the U.S. Geological Survey at the National Wetlands Research Center in Lafayette, LA, studying coastal erosion and habitat changes along the gulf coast with remote sensing and GIS. He also served as a pilot for the center, conducting aerial imagery surveys and wildlife migration studies of bear populations with aerial telemetry. Originally from Louisiana, Creed completed a Bachelor's in aviation in 1991 at Louisiana Tech University and subsequently worked as a commercial pilot and flight instructor before earning a Master's in geography from Southwest Texas State University in San Marcos, TX.

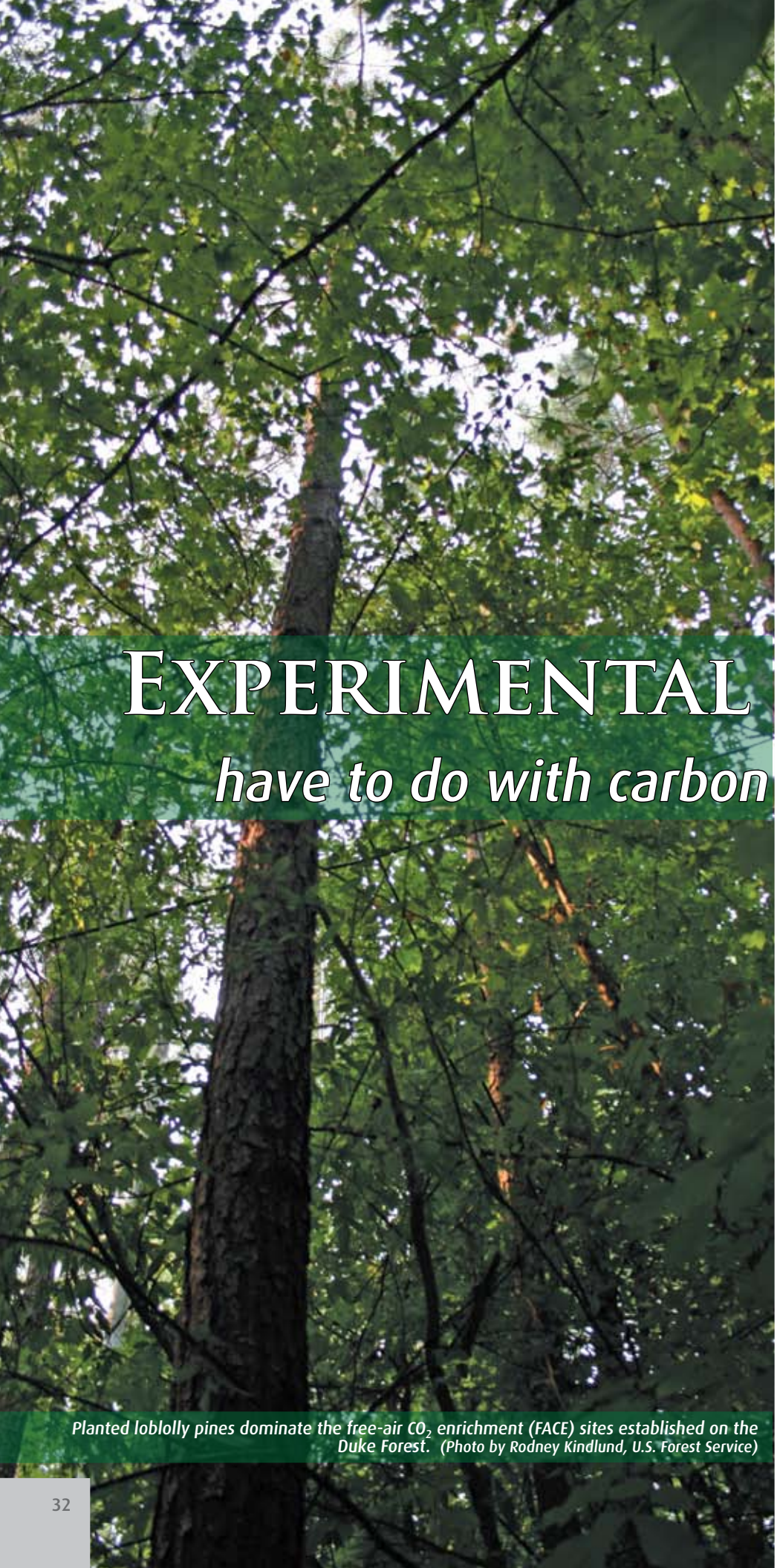
Steve Norman

Steve Norman joined EFETAC in 2005 as an ecologist. His work on the fire history and vegetation dynamics of coastal redwood forest is clarifying the tradeoffs associated with wildfire management and prescribed fire. His research is also showing that over the centuries, the interaction of changing cultures and climate has substantially altered the structure and composition of some of the most magnificent forests on Earth. Norman joined the **Pacific Southwest Station** in 2001 to help develop a comparative risk assessment framework to help planners and managers improve land management decisions. Norman was raised in the northern hardwood forests of Pennsylvania, where he developed a passion for unusual trees, remote places—and an understanding of how forests change through time. In the early 1990s, he spent 2 years as a Peace Corps volunteer in Costa Rica, where he helped farmers reforest degraded lands and improve forest management practices. He received a Ph.D. in geography from Penn State in 2002.

Qinfeng Guo

Stephen Creed

Steve Norman



Planted loblolly pines dominate the free-air CO_2 enrichment (FACE) sites established on the Duke Forest. (Photo by Rodney Kindlund, U.S. Forest Service)

Experimental Forests

what do have to do with carbon sequestration?

Duke Forest Carbon Experiments

The Duke Forest near Durham, NC, is home to a range of free-air carbon enrichment (FACE) experiments that are helping to answer questions about how forests adapt to rising levels of atmospheric carbon dioxide, and the effects of those adaptations on how and where trees store, or sequester, carbon.

In the mid-1920s, Duke University started buying small farms and woodlands as a buffer for its new campus and for possible expansion. In 1931, a total of 4,696 acres were placed under the stewardship of Dr. Clarence Korstian, dean of the Duke School of Forestry, as the Duke Forest. Over the years, using income from forest products, the university purchased more acres; today the Duke Forest covers over 7,000 acres in six main tracts located in Alamance, Durham, and Orange Counties.

The early objectives for the Duke Forest were to demonstrate practical and economical techniques for managing timber, develop an experimental forest for research in the sciences associated with growing timber, and provide an outdoor laboratory for forestry students. Since the 1990s, research on the Duke Forest has broadened beyond forestry to encompass a variety of disciplines

in the natural and environmental sciences. Today, the Duke Forest is nationally recognized as a premier facility for environmental science research, with projects sponsored by the Forest Service, U.S. Department of Energy, National Science Foundation, and National Aeronautics and Space Administration.

Fertilization and Carbon Sequestration

Duke Forest's free-air CO_2 enrichment (FACE) site is internationally known for experiments on carbon sequestration and effects of climate change. The first FACE ring (the prototype) was installed, along with a control, in 1994 in a loblolly plantation area of the Duke Forest. Since 1994, six additional rings have been installed. From above, a FACE plot looks like a circle drawn onto an expanse of loblolly pine trees; the circle is ringed with tubes that release CO_2 into the forest canopy through computer-controlled valves, the output automatically adjusted to account for the ambient movement of air. The CO_2 levels are set at about one and a half times today's levels to approximate the levels predicted for the year 2050.

SRS team leader and research physiologist **Kurt Johnsen** and fellow scientists **Chris Maier** and **John Butnor** with the **SRS Southern Institute of Forest Ecosystem Biology Team** began experiments on carbon cycling and fertilization on the first prototype plot in the 1990s. The studies they conduct with Duke researchers Ram Oren, Heather McCarthy, and others have become the longest running forest experiment in the world using FACE technology.

In 1998, to begin evaluating whether future forest growth and carbon sequestration is dependent on site fertilization, the researchers inserted a barrier across both the prototype plot and its control, fertilizing half of each twice every year with ammonium nitrate. Results from these studies have provided important information about what will happen to pine plantations under elevated CO_2—and how they could be managed under those conditions for both timber and carbon sequestration benefits.

"Because this is the longest running elevated CO_2 experiment on forest trees, we've been able to really look at the interaction between soil nutrition and CO_2 in terms of growth and processes in loblolly pine," says Johnsen. "Our findings have clear implications for the use of pine plantations for short-term carbon sequestration as well as broader implications about the role of forests as carbon sinks."

On a single plot, researchers are able to show what happens under elevated CO_2 with and without enrichment of the nutrient-poor soil that's the norm across most of the South. As you might expect, growth in the unfertilized halves starts to slow and carbon storage drop under the elevated CO_2 conditions predicted for the future. Interestingly, it is belowground where carbon starts to be lost. Trees fare much better in the fertilized halves of the plots.

In 2005, recognizing the importance of the nutrient studies on the prototype plot, researchers with studies on the remaining Duke Forest FACE facilities decided to partition their plots and fertilize half of each. Along with research on direct responses to elevated CO_2, scientists using the FACE plots continue to gather data about tree physiology that is, in turn, incorporated into models to predict forest responses to both environmental and management changes.

Narrowing It Down

In 2006, SRS and Duke collaborators published findings that provide a more precise understanding of what happens to the ability of trees to sequester carbon under elevated CO_2. They found that trees can only increase wood growth from elevated CO_2 if there is enough leaf area to support that growth. Leaf area, in turn, is limited by soil nutrition; without adequate soil nutrition, trees respond to elevated CO_2 by transferring carbon belowground then recycling it back to the atmosphere through respiration.

"With sufficient soil nutrition, forests increase their ability to tie up, or sequester, carbon in woody biomass under increasing atmospheric CO_2 concentrations," says Johnsen. "With lower soil nutrition, forests still sequester carbon, but cannot take full advantage of increasing CO_2 levels. Due to land use history, many forests are deficient in soil nutrition, but forest management—including fertilization—can greatly increase growth rate and wood growth responses to elevated atmospheric CO_2."

The researchers further tested their hypotheses using data from FACE sites in Wisconsin, Colorado, and Italy. In the 2006 articles, the scientists identify critical areas for further study, but the overall consistency they found across these diverse forests bodes well for developing accurate models to predict the ability of the world's forests to sequester carbon.

Along Comes an Ice Storm

On December 4, 2002, the Research Triangle area of North Carolina was hit with an ice storm that pulled power lines to the ground and left thousands from Raleigh to Durham in the dark. In the Duke Forest, planted pines took a beating. While young trees were flexible enough to bend without

Carbon dioxide is piped out to FACE sites on the Duke Forest from a central automated unit supplied by tanker trucks. (Photo by Rodney Kindlund, U.S. Forest Service)

Duke Forest

breaking and most older trees (over 30 years) were strong enough to take the weight of the ice, middle-aged pines snapped off at the top, their broken limbs littering the forest floor. The Duke Forest resource manager estimated it would take over $55,000 to clean up the mess.

On the FACE site, some 30 percent of the trees in the experimental plots were damaged. "At first we were quite dismayed by this ice storm because we thought it had wrecked our experiment," says Johnsen. "To adjust our data, we needed to quantify how much destruction had taken place, so we pulled everything back to the lab and started measuring."

What they found was a surprising pattern in the destruction. "The trees under high CO_2 had consistently less damage from the ice storm than those in ambient conditions," says Johnsen. "There were fewer damaged trees, and less damage per tree. We still don't know exactly why, though I suspect it's because they have bigger branches. We won't be able to tell until we harvest the trees and measure them."

The results may provide an important clue about what will happen to loblolly pine under global warming. "Freezing weather limits the current range of loblolly pine, since the tree is susceptible to damage from cold and ice," says Johnsen. "We're seeing that elevated CO_2 increases the production of seed and cones in loblolly pine. If it also decreases damage from ice storms, loblolly pine could start migrating north under climate change conditions." —*ZH*

For more information:

Kurt Johnsen at 919-549-4012 or kjohnsen@fs.fed.us

A Natural History of Loblolly Pine

The Poster Child for Forest Carbon Research

by Kurt Johnson

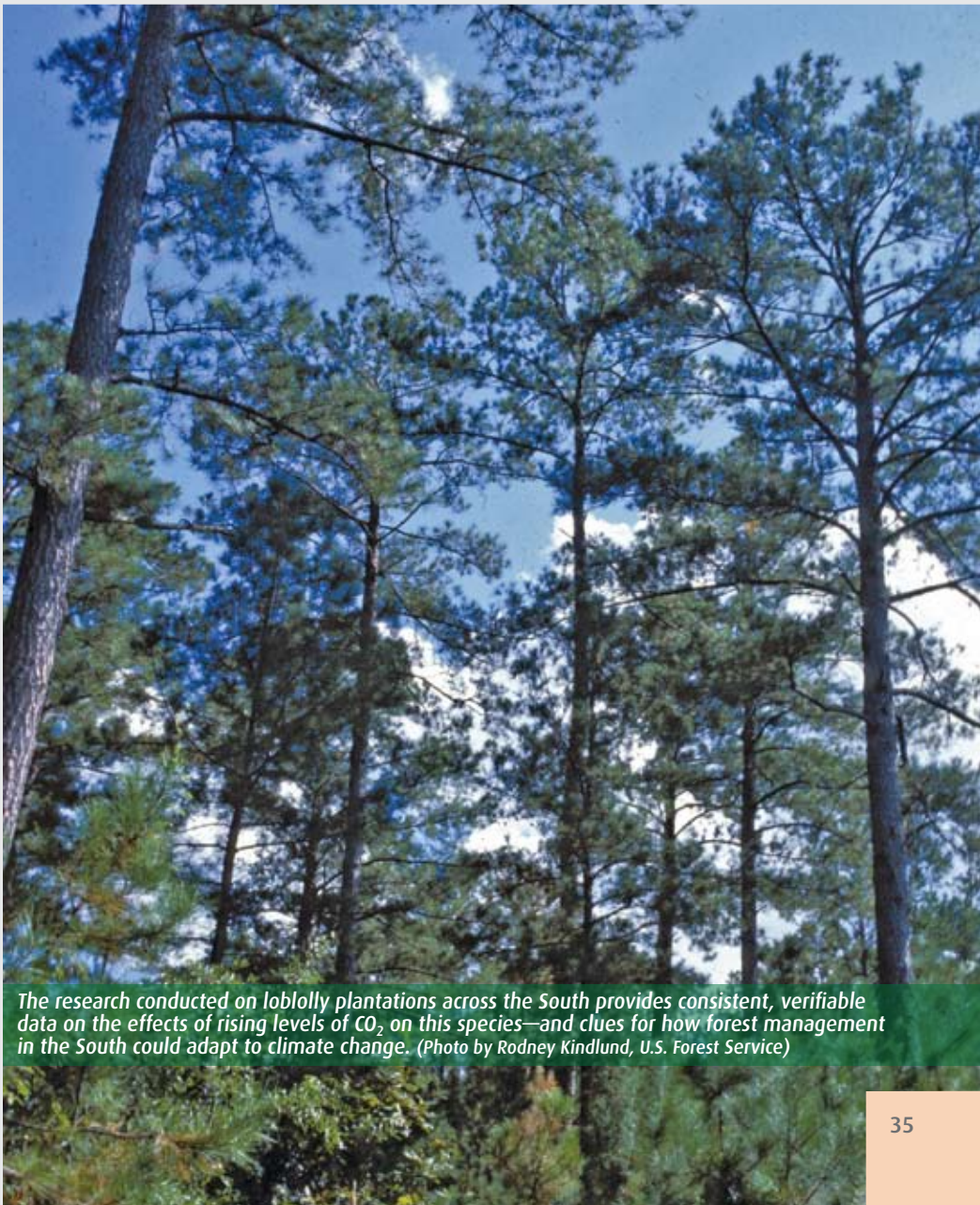
Loblolly pine, though native to the South, doesn't do well in shade and is not fire resistant. Before European settlement, these characteristics meant that the tree's extent—where it will live—was much more limited than it is today. Though it occurred across a region ranging from the Coastal Plain through the Piedmont to the gulf coast, loblolly pine was mostly restricted to narrow, wet habitats in low-drainage areas that came to be called "loblollies." Across the southern half of its range, loblolly was largely excluded due to fire, which allowed the fire-dependent longleaf pine to thrive. In the northern part of its range, loblolly's extent was reduced due to natural succession toward long-lived, shade-tolerant hardwoods.

During the 19th and early 20th centuries, except for particularly difficult sites (usually wetlands), most southern forests were cut over, initially to provide pasture and agricultural land. After the Civil War, most of the remaining old-growth forest was cut to supply rapid industrial growth.

Meanwhile across the Coastal Plain and Piedmont—one after another—the farmlands cleared from forests were abandoned, the soil worn out from poor agricultural practices. Because its light seed is easily carried on the wind and it can survive and grow in poor soil, loblolly pine began to move into many of the old fields naturally; then it made sense to start growing the tree for timber on land that wouldn't support much else.

Wildfire control, followed by the rise of plantation forestry, increased loblolly pine acreage in the Southeast, particularly from the 1950s through the end of the 20th century. Today, there are approximately 26 million acres of loblolly pine plantations in the Southeast, and another 18 million acres of naturally regenerated loblolly forests. Due to its ability to thrive under diverse conditions, loblolly not only holds promise as an adaptable plantation species during times of rapid climate change, but as reliable stock for reestablishing forests on land degraded by catastrophe or depleted by unwise farming practices. *—KJ*

Kurt Johnson leads the SRS Southern Institute of Forest Ecosystems Biology Team based in Research Triangle Park, NC.



The research conducted on loblolly plantations across the South provides consistent, verifiable data on the effects of rising levels of CO_2 on this species—and clues for how forest management in the South could adapt to climate change. (Photo by Rodney Kindlund, U.S. Forest Service)

science science

You Can Use!

You Can't Always Get What You Want

My Experience Building an Earth Friendly Home

by Steve McNulty

After 17 years studying global climate change in Raleigh, NC, I'm convinced that the change occurring in our planet's atmosphere may well be the greatest threat that we face as a nation. As a concerned citizen, I feel it's my duty to start taking steps to reduce my own contributions to the rise in greenhouse gases and global warming. So when my family and I started thinking about building a new house, I knew I had to incorporate energy efficiency into the design. The question was how to do that cost effectively.

I started out by reading about a dozen books on home design and energy saving. I learned that, ideally, a house should be sited with the longest sides oriented in a north/south direction. That seemed easy enough.

Second, I learned that if you want to take advantage of passive solar energy, you should design the roof overhangs to allow winter sunlight in while keeping most of the summer light out. This would reduce the need for summer cooling and winter heating. I was all for that.

After much searching, I found a beautiful 5-acre piece of land in northern Wake County, NC, that sat 100 feet above a small private lake surrounded by hundreds of acres of (at least currently) undeveloped land. Great! Unfortunately the orientation of the house to the lake would have to be east/west, not north/south. "That's okay," I thought. I could still build a passive solar home and make up some of the loss in orientation. Then I found out that most passive solar houses are ranch style, and given the need for bedrooms for our large family, the cost of building a ranch style home large enough (an estimated 4,400 square feet) to accommodate our needs was impractical.

Not a good start. Oh, and one more thing. The site had a stunning view of the lake, so I wanted lots of windows facing the water. I read that while the extra glass would reduce the need for interior lighting, windows are notoriously poor insulators compared to solid walls. But to be near water and not see it, impossible!

As a long-time climate change researcher, I was used to adversity. So with shovel in hand, I began to dig myself out of the energy use hole that I had created for myself.

But You Just Might Find ...

My task was to reduce heating and cooling energy use for 4,400 square feet of heated space. After some Internet surfing, I learned that building supply manufactures have developed oriented strand board (OSB) with an aluminum side designed to reflect heat. Most heat exchange actually occurs through the roof, so I decided to cover the roof in the reflective material and use traditional (uncoated) OSB for the side walls. The cost of the reflective OSB was about $3 more per 4- by 8-foot panel compared to the uncoated panels; the total cost for the roof upgrade was about $500.

Next I needed to address the windows, which took up 23 percent of the total wall space of the house. Wherever possible, I used fixed glass panels, which reduce air transfer. Since they are less expensive to build and install than other options, I was able to have them built as double panes with an argon gas-filled interior that can reduce solar radiant heat by 80 percent. By combining these options, I ended up not paying any extra for the windows, and greatly improved home energy efficiency.

The windows were set, so it was time to turn my attention toward the other 77 percent of the exterior space, i.e., the walls and doors. First, I looked at insulating the walls. There are some really remarkable products on the market these days; insulated concrete forms—basically poured concrete forms made out of insulated foam—are very attractive as building materials. Though the norm in Europe, this very energy efficient form of construction is still relatively new here and very expensive.

So I decided to use blown insulation in the walls. An air permeable mesh was placed over the stud walls, and the insulating material blown into the cavity. Made mostly from recycled newspaper, this material seals much better than traditional fiberglass batting (the pink stuff that comes on a roll), and uses material that would otherwise go into a landfill; the good news is that blown insulation for the whole house only cost $400 more than traditional fiberglass batting. Cellulose foam was another attractive option, but the cost for my house would have been three times that of the blown insulation ($14,000 vs. $5,000).

All the major door manufacturers sell insulated exterior doors that cost only a little more than hollow core versions, so that was an easy choice to make. Whenever possible, I used doors and other materials from the local Habitat for Humanity Recycle Center (HHRC), which always has wonderful donated new and used material. Another plus is that proceeds from the sales go towards building new homes for low-income families. I found a beautiful front door that had been special ordered at one of the local hardware stores and never picked up. The store had donated the $3,300 door to HHRC, where I bought it for $1,000.

You Get What You Need

After the house was completed, I was anxious to see if all my attempts at energy savings paid off. I was very pleased to see my July utility bill was $178, which was about half the bill from my previous smaller—but far less energy efficient—home. Raleigh had eight (yes, eight!) record highs in August, but I experienced far less dread about what the mail would bring me!

Steve McNulty is team leader of the SRS Southern Global Change Team located in Raleigh, NC.

Loblolly female pine cones. (Photo by Erich Vallery, U.S. Forest Service - SRS-4552, www.bugwood.org)

Forest Management Strategies for Coping with Likely Climate Changes

rising sea levels

- Plant mangroves and other soil-retaining vegetation to delay coastal beach erosion for as long as reasonably possible.

increased wildfires

- Manage and encourage more fire-tolerant tree species such as longleaf pine rather than more susceptible species such as loblolly pine.
- Increase public education and preparedness regarding wild fire prevention and individual preparation and control.

For more information *or assistance on wildland-urban interface issues, visit Interface South at: www.interfacesouth.org, or contact Annie Hermansen Báez, 352–376–3271 or ahermansen@fs.fed.us.*

increased soil erosion

- Continue to encourage standard soil erosion control practices—buffers, filter strips, broad-based dips, and piling slash downslope of skid trails and along streams.

For more information *on erosion control in forest lands contact Johnny Grace, 334–826–8700 ext. 29 or jmgrace@fs.fed.us.*

- Relocate trails away from streams.
- Use bridge mats and culverts at stream crossings.

changing forest productivity

- Shift the northern limit of traditional pine range.
- Favor more drought-tolerant tree species.
- Decrease stand-stocking level to reduce drought and insect impacts.
- Shorten rotation length to minimize the potential of volume loss from disturbances.

Adapted from: McNulty, S. 2007. Climate change impacts on Southern U.S. forests: adaptation options for forest managers. Presentation to the Southern Group of State Foresters.

(Photo by Zoë Hoyle, U.S. Forest Service)

Where to Start? 10 Things You Can Do To Make a Difference

1. **Walk**, ride a bicycle, use public transit, or carpool. If you have to drive, use a small car. Think about moving closer to work and your other daily destinations.

2. **Fly less.** Use videoconferencing instead of attending meetings. Take vacations closer to home.

3. **Eat locally.** Raise food in a home garden (requires no fossil fuel) or buy from local, organic sources. Eat low on the food chain, and make the most of seasonal foods.

4. **Heat efficiently.** Insulate and seal leaks in the attic and basement. Replace leaky windows with ENERGY STAR qualified windows.

5. **Use less air conditioning.** Install ceiling fans. Retain or plant shade trees around your home.

6. **Replace those light bulbs.** The new compact fluorescent bulbs are 75 percent more efficient than standard bulbs. The U.S. Environmental Protection Agency estimates that if every household in the United States changed 5 light bulbs, we could prevent greenhouse gases equal to the emissions from nearly 10 million cars!

7. **Buy energy-efficient products.** Look for ENERGY STAR qualified products in more than 50 product categories that include lighting, home electronics, and heating and cooling equipment and appliances.

8. **Use less water.** Municipal water systems use a lot of energy to purify and distribute water to our houses. Only water your yard if you absolutely have to, and only during the coolest part of the day. Turn the water off when you're brushing your teeth. Fix leaky faucets and toilets.

9. **Reduce, reuse, and recycle.** Think about repairing and reusing items rather than replacing them. Recycle paper, plastic containers, and other goods. Support recycling markets by buying products made from recycled materials.

10. **Take it to the garden.** Use a push mower or a scythe to cut your grass; use a rake or broom instead of a leaf blower. Replace grass with native ground covers. Compost your food and yard wastes; use compost to improve soil rather than fertilizers.

For more information:

EPA Climate Change-What You Can Do: http://www.epa.gov/climatechange/wycd/home.html

EPA ENERGY STAR: http://www.energystar.gov/

RECOMMENDED READING

The Fate of Southern Forests

Joyce, L.; Aber, J.; McNulty, S. [and others]. 2001. Potential consequences of climate variability and change for the forests of the United States. In: National Assessment Synthesis Team, eds. Climate change impacts on the United States. Cambridge, UK: Cambridge University Press: 489–524.

Wear, D.N. 2005. Future forestland area in the U.S. South. In: Shupe, T.F.; Dunn, M.A., eds. Proceedings of Louisiana Natural Resources Symposium. Baton Rouge, LA: Louisiana State University Ag Center Research & Extension: 32–41.

Wear, D.N.; Carter, D.R.; Prestemon, J. 2007. The U.S. South's timber sector in 2005: a prospective analysis of recent change. Gen. Tech. Rep. SRS–99. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 29 p.

That Carbon Dance

Butnor, J.R.; Johnsen, K.H.; Oren, R.; Katul, G.G. 2003. Reduction of forest floor respiration by fertilization on both carbon dioxide-enriched and reference 17-year-old loblolly pine stands. Global Change Biology. 9: 849–861.

Johnsen, K.; Maier, C.; Sanchez, F. [and others]. 2007. Physiological girdling of pine trees via phloem chilling: proof of concept. Plant, Cell and Environment. 30: 128–134.

Johnsen, K.; Wear, D.N.; Oren, R. [and others]. 2001. Carbon sequestration and southern pine forests. Journal of Forestry. 99(4): 14–21.

McCarthy, H.R.; Oren, R.; Finzi, A.C.; Johnsen, K.H. 2006. Canopy leaf area constrains [CO_2]-induced enhancement of productivity and partitioning among aboveground carbon pools. Proceedings of the National Academy of Sciences. 103(51): 19,356–19,361.

Ins and Outs of the Carbon Cycle

Butnor, J.R.; Doolittle, J.A.; Johnsen, K.H.; Samuelson, L., [and others]. 2003. Utility of ground-penetrating radar as a root biomass survey tool in forest systems. Soil Science Society of America Journal. 67: 1,607–1,615.

Butnor, J.R.; Johnsen, K.H. 2004. Calibrating soil respiration measures with a dynamic flux apparatus using artificial soil media of varying porosity. European Journal of Soil Science. 55: 639–647.

We're All Downstream

Lu, J.; Sun, G.; Amatya, D.M.; Harder, S.V.; McNulty, S.G. 2006. Understanding the hydrologic response of a Coastal Plain watershed to forest management and climate change in South Carolina, U.S.A. In: Williams, T., ed. Hydrology and management of forested wetlands: Proceedings of the international conference. St. Joseph, MI: American Society of Agricultural and Biological Engineers: 231–239.

McNulty, S.G.; Sun, G.; Moore Myers, J. 2004. Climate, population and vegetation cover change impacts on water yield and demand across the Southern U.S. In: Proceedings of Geographic Information Systems and water resources III, American Water Resources Association spring specialty conference. Nashville, TN: American Water Resources Association. 11 p.

Sun, G.; McNulty, S.G.; Lu, J.; Amatya, D.M. [and others]. 2005. Regional annual water yield from forest lands and its response to potential deforestation across the Southeastern United States. Journal of Hydrology. 308: 258–268.

Sun, G.; McNulty, S.G.; Moore, J. 2004. Modeling the potential effects of forest management and climate change on water yield across the Southeastern U.S. In: U.S. first interagency conference in watersheds. Benson, AZ: [publisher unknown]: 346–353.

Going Up Turkey Creek

Amatya, D.M.; Sun, G.; Skaggs, R.W.; Chescheir, G.M.; Nettles, J.E. 2006. Hydrologic effects of global climate change on a large drained pine forest. In: Williams, T., ed. Hydrology and management of forested wetlands: Proceedings of the international conference. St. Joseph, MI: American Society of Agricultural and Biological Engineers: 583–594.

Harder, S.V.; Amatya, D.M.; Callahan, T.J.; Trettin, C.C.; Hakkila, J. 2007. Hydrology and water budget for a forested Atlantic Coastal Plain watershed, South Carolina. Journal of The American Water Resources Association: 43(3): 563–575.

Sun, G.; McNulty, S.G.; Lu, J.; Amatya, D.M. [and others]. 2005. Regional annual water yield from forest lands and its response to potential deforestation across the Southeastern United States. Journal of Hydrology. 308: 258–268.

Too Warm for Trout?

Adams, S.B.; Bjornn, T.C. 1997. Bull trout distributions related to temperature regimes in four central Idaho streams. In: Mackay, W.C.; Brewin, M.K.; Monita, M. eds. X, X: Friends of the Bull Trout Conference Proceedings. 371–380.

Flebbe, P.A.; Roghair, L.D.; Bruggink, J.L. 2006. Spatial modeling to project Southern Appalachian trout distribution in warmer climate. Transaction of the American Fisheries Society. 135: 1,371–1,382.

Mussels: Do Not Disturb!

Dunca, E.; Mutvei, H. 2001. Comparison of microgrowth pattern in Margaritifera margaritifera shells from south and north Sweden. American Malacological Bulletin. 16: 239–250.

Haag, W.R.; Warren, M.L. 2007. Freshwater mussel assemblage structure in a regulated river in the Lower Mississippi River Alluvial Basin, USA. Aquatic Conservation: Marine and Freshwater Ecosystems. 17(1): 25–36.

Froglogging in East Texas

Saenz, D.; Fitzgerald, L.A.; Baum, K.A.; Conner, R.N. 2006. Abiotic correlates of anuran calling phenology: the importance of rain, temperature, and season. Herpetological Monographs. 20: 64–82.

High Level Problems for Songbirds

Simons, T.R.; Rabenold, K.N.; Buehler, D.A.; Collazo, J.A.; Franzreb, K.E. 1999. The role of indicator species: neotropical migratory song birds. In: Peine, J., ed. Ecosystem management for sustainability: principles and practices illustrated by a regional biosphere reserve cooperative. Boca Raton, FL: CRC Press, Lewis Publishers: 187–208.

Turning Up the Heat

Joyce, L.; Aber, J.; McNulty, S. [and others]. 2001. Potential consequences of climate variability and change for the forests of the United States. In: National Assessment Synthesis Team, eds. Climate change impacts on the United States. Cambridge, UK: Cambridge University Press: 489–522.

Guo, Q.F. 2006. Intercontinental biotic invasions: what can we learn from native populations and habitats? Biological Invasions. 8(7): 1,451–1,459.

What Do Experimental Forests Have to Do with Carbon Sequestration?

McCarthy, H.R.; Oren, R.; Kim, H.-S. [and others]. 2006. Interaction of ice storms and management practices on current carbon sequestration in forests with potential mitigation under future CO_2 atmosphere. Journal of Geophysical Research. 111: 1–10.

Oren, R.; Ellsworth, D.S.; Johnsen, K.H.; Phillips, N. [and others]. 2001. Soil fertility limits carbon sequestration by forest ecosystems in a CO_2-enriched atmosphere. Nature. 411: 469–472.

Palmroth, S.; Oren, R.; McCarthy, H.R.; Johnsen, K.H. [and others]. 2005. Aboveground sink strength in forests controls the allocation of carbon below ground and its [CO_2]-induced enhancement. Proceedings of the National Academy of Sciences. 103(51): 19,362–19,367.

around the STATION...

Experimental Forests

1	Bent Creek	NC
2	Blue Valley	NC
3	Coweeta	NC
4	John C. Calhoun	SC
5	Santee	SC
6	Scull Shoals	GA
7	Hitchiti	GA
8	Olustee	FL
9	Chipola	FL
10	Escambia	AL
11	Tallahatchee	MS
12	Delta	MS
13	Harrison	MS
14	Palustris	LA
15	Stephen F. Austin	TX
16	Crossett	AR
17	Alum Creek	AR
18	Sylamore	AR
19	Henry F. Koen	AR

SRS Shares $6 Million USDA Award

The **SRS Southern Institute of Forest Genetics** (SIFG) led by **Dana Nelson** will receive funding from a $6 million grant announced on August 31, 2007, by Agriculture Secretary Mike Johanns. The grant will support research to improve genomic-based breeding technologies for conifer trees through the Conifer Translational Genomics Network (CTGN), a collaborative effort in agriculture and forestry research to provide tree breeders with new tools to enhance and accelerate tree improvement.

David Neale (University of California–Davis) is the principal investigator for the grant, which includes 11 other university and Federal research collaborators. SIFG, based in Saucier, MS, will serve as the Genetic Stocks Center for archiving important genotypes of loblolly pine. Approximately 1,000 genotypes will be grafted and maintained as stock by SIFG for current and future use in the research and outreach efforts of the CTGN. SIFG researchers and the CTGN project team will focus on associating specific DNA sequences with specific attributes such as growth rate, tree form, wood quality, stress tolerance, and disease resistance. The **Pacific Northwest Research Station** will develop a similar stock center for Douglas fir in Corvallis, OR.

Awards

Wendell Haag, fisheries wildlife biologist with the aquatic and terrestrial fauna team of the **SRS Center for Bottomland Hardwoods Research** (CBHR), has received the Forest Service Chief's Early Career Scientist Award for "high productivity of quality research on freshwater mussels."

Michael Rauscher, retired, has received the Forest Service Chief's Technology Transfer Award for "innovation, vision, and persistence in the conception, design, and implementation of the Forest Encyclopedia Network."

Kas Dumroese, team leader of the nursery and reforestation technology team of the **SRS National Agroforestry Center**, received the 2007 Celebrating Wildflowers Award-Excellence in Native Plant Materials Management, from the Forest Service, Vegetation Ecology, Rangeland Management, Washington Office, for "initiating the Native Plants Journal, the Native Plants Propagation Protocol Database, and developing native plant work with American Indians."

Jeremy Pinto, botanist with the nursery and reforestation technology team of the **SRS National Agroforestry Center**, received the 2007 Earle R. Wilcox Memorial Individual Achievement Award, Pacific Northwest Region, from the Intertribal Timber Council for his work in assisting American Indians develop nursery programs and produce native plants.

New Staff at the Center for Bottomland Hardwoods Research

Dr. Mark H. Eisenbies began October 1, 2007, as a research hydrologist at the **Center for Bottomland Hardwoods Research**, and will be located in the forestry school on the campus of Mississippi State University. Eisenbies completed his Ph.D. degree in forestry in 2004 at Virginia Tech; his Master's degree in soil science is from the University of Tennessee, Knoxville. Eisenbies is no

stranger to SRS, having worked for the **SRS Center for Forested Wetlands Research**, Charleston, SC, from 1996 to early 2000, when he decided to go back to school for his Ph.D. He will be researching issues related to the hydrology of lowland forests and landscapes in the Mississippi alluvial floodplain and other associated systems.

Dr. Mason "Buck" Bryant is the new research fisheries biologist at CBHR. Bryant transferred from Juneau, AK, where he worked with the Aquatic and Land Interactions Program of the **Pacific Northwest Research Station**. Bryant is a native of Maine, with a Ph.D. from the University of Washington–Seattle. Bryant will study the fisheries of streams and rivers in the Mississippi alluvial floodplain.

Dr. Ray Souter reported in August for the position research forester-biometrician at the CBHR in Stoneville, MS. Souter will begin work on lowland hardwood growth-and-yield research. A native of Magnolia, AR, Souter has his Master's and Ph.D. degrees in forest resources from the University of Georgia.

In Memoriam

Victor Rudis, SRS research forester who died unexpectedly in November 2007, brought a great enthusiasm to his work in forest assessment. One of the first to incorporate non-forest issues into forest resource assessments across the Southern United States, he made important contributions in the areas of landscape ecology, fragmentation, invasive species, and human impacts on forest systems. His other interests included the estimation of regional accessibility, aesthetics, forest community types, old growth, recreation opportunities, and wildlife habitats. He published widely, contributing to Government reports, books, proceedings, and scientific journal articles. Rudis demonstrated genuine curiosity for and love of forest resources in the Southern United States, and brought to his work a spirit of enthusiasm, cooperation, and collaboration that will be sorely missed.

Rudis began his career with the Forest Service in 1980, and spent the past 27 years as a research forester with the **SRS Forest Inventory and Analysis** unit. He was a member of the Society of American Foresters, the Ecological Society of America, The Nature Conservancy, the Sierra Club, and Sigma XI Scientific Research Society. He was a former member and president of the Mississippi Native Plant Society. He had been an active member of the World Neighbors Association at Mississippi State University, Starkville, MS, where he and his family served as a host family for numerous international students.

What does the future hold for Southern forests and the people who depend on them? What issues are you most concerned about?

The Forest Service and the Southern Group of State Foresters are starting a 2-year project to forecast the future of forests in the southern 13 States and parts of the Caribbean. Led by the Southern Research Station and the Southern Region and conducted by teams of scientists across the South, the Southern Forest Futures Project (SFFP) will build on sources such as the Southern Forest Resource Assessment to project possible scenarios based on the issues of most interest to natural resource professionals and the general public.

During February and March, SFFP held a series of public workshops to gather input on the forces of change most likely to influence forest conditions, and on the values that will be put at risk from these changes. Input from the workshops, some of which were also Webcast, will be used to shape the final plans for the SFFP. If you were not able to attend the meetings, you can provide your input through the SFFP website:

www.srs.fs.usda.gov/futures.

(U.S. Forest Service photo)

Southern Research Station headquarters in winter. (Photo by Rodney Kindlund, U.S. Forest Service)

NEW PRODUCTS

natural resources inventory and monitoring

1 Bentley, James W.; Harper, Richard A. 2007. **Georgia harvest and utilization study, 2004.** Resour. Bull. SRS-117. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 25 p.

In 2004, a harvest and utilization study was conducted on 96 operations throughout Georgia. There were 2,368 total trees measured; 1,581 or 67 percent were softwood, while 787 or 33 percent were hardwood. Results from this study showed that 86 percent of the total softwood volume measured was utilized for a product, while the other 14 percent was left as logging residue. Seventy-four percent of the total hardwood volume measured was utilized for a product, while 26 percent was left as logging residue.

2 Brown, Mark J. 2007. **Florida's forests—2005 update.** Resour. Bull. SRS-118. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 39 p.

This bulletin highlights principal findings of an annual inventory of Florida's forests. Data summaries are based on measurements of 60 percent of the plots in the State. Additional data summaries and bulletins will be published as the remaining plots are measured.

3 Johnson, Tony G.; Steppleton, Carolyn D. 2007. **Southern pulpwood production, 2005.** Resour. Bull. SRS-116. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 42 p.

Southern pulpwood production was 64.0 million cords in 2005, up from 63.8 million cords in 2004. Roundwood production declined 2 percent to 46.2 million cords in 2005 and accounted for 72 percent of total pulpwood production. Use of wood residue increased 6 percent to 17.8 million cords. Alabama led the South in total production

at 10.2 million cords. In 2005, 87 mills were operating and drawing wood from the 13 Southern States. Pulping capacity of southern mills declined from 125,182 tons per day in 2004 to 124,567 tons per day in 2005, but still accounted for more than 70 percent of the Nation's pulping capacity.

4 Oswalt, Christopher M.; Oswalt, Sonja N. 2007. **Winter litter disturbance facilitates the spread of the nonnative invasive grass *Microstegium vimineum* (Trin.) A. Camus.** Forest Ecology and Management. 249: 199-203.

We studied the impacts of winter litter disturbance on the spread of the non-native invasive plant *Microstegium vimineum* (Japangrass). After one growing season, plots receiving leaf litter removal treatments experienced a spread of Japangrass 4.5 times greater than undisturbed (control) plots. Our results suggest that winter litter removal as a result of harvest activities, floodwater scour, or animal activities can drastically increase Japangrass spread and may enhance potential ecological impacts of invasions by increasing Japangrass cover. This study suggests one mechanism facilitating rapid expansion of Japangrass following site disturbance, and indicates that Japangrass can experience rapid growth in response to site disturbance even in the absence of canopy removal.

5 Oswalt, Sonja N.; Johnson, Tony G. 2007. **The status of North Carolina's national forests, 2002.** e-Resour. Bull. SRS–115. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. http://www.srs.fs.usda.gov/pubs/rb/rb_srs115.pdf [Date accessed: October 26, 2007].

This bulletin describes forest resources of the Pisgah/Cherokee, Nantahala, Croatan, and Uwharrie National Forests in the State of North Carolina. It is based on sampling conducted by the U.S. Department of Agriculture, Forest Service, Southern Research Station, Forest Inventory and Analysis research work unit. This bulletin addresses forest area estimates; timber growth, removals and mortality; and timber product output.

6 Randolph, KaDonna C.; Seaver, Bill. 2007. **An alternative to traditional goodness-of-fit tests for discretely measured continuous data.** Forest Science. 53(5): 590-599.

A basic task in scientific research is to determine the extent to which two independent samples differ from one another. This is often accomplished by comparing the data distributions through goodness-of-fit tests. Such tests are most useful when the data are measured on a continuous scale, or when they are discretely grouped into several categories. Application of the goodness-of-fit tests to discrete data can be limited when some of the categories include very few observations. This paper addresses this limitation by presenting an alternative goodness-of-fit test that accommodates discretely measured continuous datasets with sparsely populated categories. The proposed methodology provides great flexibility in analysis and interpretation, and should find application in a variety of scientific inquiries.

7 Roesch, Francis A. 2007. **The components of change for an annual forest inventory design.** Forest Science. 53(3): 406-413.

The sample design of the U.S. Forest Service's Forest Inventory and Analysis Program (FIA) is described in terms of a population consisting of forest area in two dimensions and time in the third dimension. The population is subdivided by a set of discrete change component matrices that are, in turn, compared to traditional components of growth. The paper explores some special problems that arise due to unique features of the FIA sample design. Finally, the traditional definitions are shown to be at a theoretical disadvantage to those presented in the paper because the former are sample design dependent, while the latter are based entirely on population attributes.

forest ecosystem restoration and management

8 Boerner, R.E.J.; Waldrop, T.A.; Shelburne, V.B. 2007. **Wildfire mitigation strategies affect soil enzyme activity and soil organic carbon in loblolly pine (*Pinus taeda*) forests.** Canadian Journal of Forest Research. 36: 3148-3154.

Effects of three wildfire hazard reduction treatments were quantified on mineral soil, organic carbon, and enzyme activity in loblolly pine forests on the Piedmont of South Carolina. Piedmont soils were subjected to frequent fire and farming until the 1930s. The intensively cultivated soils were further degraded by erosion until reforestation with pines, primarily loblolly. Fuels have accumulated since reforestation, making these areas susceptible to wildfires. This study is part of the National Fire and Fire Surrogate Study, which uses burning, thinning, and the combination to reduce wildfire hazard. This study focused on two questions. (1) How do thinning and burning, alone or combined, affect soil organic carbon and the soil carbon/nitrogen ratio in these degraded soils? (2) How do wildfire hazard mitigation strategies affect the activity of soil enzymes produced by the microbial assemblage in these soils?

9 Bragg, Don C. 2006. **Potential contributions of figured wood to the practice of sustainable forestry.** Journal of Sustainable Forestry. 23(3): 67-81.

The birdseye grain of sugar maple (*Acer saccharum* Marsh.) can showcase the potential of figured wood in sustainable forestry. This poorly understood but valuable grain abnormality commands

such a premium that its presence alone can influence timber management. Good forestry and logging practices can help assure that quality birdseye maple logs are not relegated to low-value uses. Birdseye specialty markets have also developed, creating opportunities for pieces of small or irregular dimensions. Even though few have the same promise as birdseye maple, figured grains are found in virtually every tree species, thus increasing the potential for other high-value niche markets. However, the relative rarity and slow formation of figured grains threaten their sustainability, until more research on their genetics, propagation, and silviculture becomes available.

10 Bragg, Don C. 2007. S. Mansourian, D. Vallauri, and N. Dudley (eds.): **Forest restoration in landscapes: beyond planting trees.** Landscape Ecology. 22: 477-479.

Global-scale climate change, a burgeoning human population, and rapid expansion of the world's economy have placed incredible pressures on environmental systems to sustain their production of goods and services. Furthermore, our frontiers are exhausted—we must learn to make due with the landscapes we have already exploited. To this end, the Worldwide Fund for Nature (formerly the World Wildlife Fund or "WWF") has initiated a global program of large-scale forested landscape restoration. *Forest Restoration in Landscapes* is a compilation of WWF experiences in the establishment, maintenance, and evaluation of these efforts. I appreciate that the WWF's view on restoring forested landscapes transcends simple species conservation to embrace socio-economic realities. Even with some weaknesses in content and format, I believe this book reflects a reasoned approach to livable, working landscapes that recognizes needs of both human and natural communities.

11 Butnor, John R.; Johnsen, Kurt H.; Wikström, Per. 2006. **Imaging tree roots with borehole radar.** In: 11th international conference on ground penetrating radar. Additional information: http://gpr.osu.edu. [Date accessed: June 28, 2006].

On amenable soils, ground-penetrating radar has been used to accurately detect and map lateral tree roots using surface-based antennas in reflection mode. In some tree species (e.g., *Pinus taeda*, *Pinus palustris*), vertically orientated tap roots directly beneath the tree comprise most of the root mass. It is difficult if not impossible to vertically delineate these roots with surface-based radars. In August 2003 a collaborative project between the U.S. Forest Service, Southern Research Station, Radarteam AB, and the Swedish University of Agricultural Sciences was undertaken to assess the potential of high-frequency borehole radar to detect vertical, near-surface reflectors resulting from tree roots. Crosshole tomography provided excellent information on the depth of tree roots, but was less useful for imaging near surface features. Borehole-to-surface measures provided the best information on the near surface, where the bulk of roots are found. The technique has promise in forest research, but the development of new high-frequency borehole antennas and forward modeling software that allows concurrent processing of travel-time and amplitude data is necessary to further this research.

12 Conner, Richard N.; Saenz, Daniel. 2005. **The longevity of large pine snags in eastern Texas.** Wildlife Society Bulletin. 33(2): 700-705.

Habitat for cavity-nesting wildlife and forest biodiversity are closely tied to the availability of standing dead trees (snags). Large snags (> 40 cm diameter at breast height) are particularly important because they provide habitat for both large and small cavity users. We studied the falling of large pine snags in eastern Texas over a 20-year period (1983–2003) to determine how long these large pine snags remained standing. We monitored 136 large snags and determined that 92 snags (67.6 percent) were still standing after five years. Ten years after tree death, 21 snags (15.4 percent) were still standing, indicating the long-term value of these large snags for wildlife.

(Photo by Zoë Hoyle, U.S. Forest Service)

13 Greenberg, Cathryn H.; Tomcho, Aimee Livings; Lanham, J. Drew [and others]. 2007. **Short-term effects of fire and other fuel reduction treatments on breeding birds in a Southern Appalachian upland hardwood forest.** Journal of Wildlife Management. 71(6): 1906-1916. [Editor's note: Station scientist Thomas A. Waldrop co-authored this publication.]

Land managers need to know how fuel reduction methods affect breeding birds to manage bird communities in conjunction with wildfire risk management or other management objectives. We used a replicated experimental design to compare bird response to (1) prescribed burning; (2) mechanical understory reduction; (3) mechanical + burning (MB); and (4) controls in the Southern Appalachians. Many bird species showed no detectable response to treatments. Bird species richness, total density, and densities of indigo buntings, eastern bluebirds, and eastern wood-pewees were highest in MB; hooded, worm-eating, and black-and-white warblers showed short-term declines in some or all treatments. High-intensity burning with heavy tree-kill, as occurred in MB, can be used as a management tool to increase densities of birds associated with open habitat while retaining many forest and generalist species, at least in the short term.

14 Greenberg, Cathryn H.; Warburton, Gordon S. 2007. **A rapid hard-mast index from acorn presence-absence tallies.** Journal of Wildlife Management. 71(5): 1654-1661.

Acorn crop sizes vary considerably among oak species, years, and places. This affects oak regeneration and wildlife species that depend on acorns for food. We used 21 years of acorn visual survey data in western North Carolina to develop predictive equations for hard mast indices based on the proportion of trees bearing acorns. By substituting this fast, simple method over the labor-intensive counting of twigs and acorns used in some other visual surveys, land managers can use the time savings to sample more trees to improve hard mast index accuracy. Because the proportion of trees bearing acorns is also a stand-alone index of acorn production, State and Federal agencies can easily standardize their hard mast surveys using this technique, thus ensuring that acorn production data are comparable at local and regional scales.

15 Hiers, J.K.; O'Brien, J.J.; Will, R.E.; Mitchell, R.J. 2007. **Forest floor depth mediates understory vigor in xeric *Pinus palustris* ecosystems.** Ecological Applications. 17(3): 806-814.

In restoring longleaf pine ecosystems where fire has been excluded for long periods, a closed midstory will often form. Many managers focus on eliminating midstory vegetation, assuming light or belowground competition limits understory vigor. An alternative hypothesis is that deep litter and forest floor that develops in the absence of fire inhibits understory vigor. We analyzed a dataset of monitoring plots in xeric longleaf pine stands at Eglin Air Force Base, FL. Results showed that only forest floor depth had a significant negative direct effect on understory vigor. While midstory development had no direct effect, higher midstory cover did have a significant negative indirect effect through increasing forest floor depth. Low intensity prescribed fire is an effective means to reduce forest floor and litter depth and should have a greater impact on understory vigor than removing midstory alone without reducing forest floor. Repetitive low intensity fires will likely cause a reduction in midstory cover over time.

16 Hinkelman, Travis M.; Loeb, Susan C. 2007. **Effect of woody debris abundance on daytime refuge use by cotton mice.** Southeastern Naturalist. 6(3): 393-406.

Small mammals are important components of forested ecosystems, and cotton mice are one of the most common species of small mammal found in southeastern forests. Previous research suggested that logs and snags, commonly known as coarse woody debris (CWD), are important to cotton mice in southeastern pine forests. However, the role of CWD in the ecology of these mice is not known. We examined daytime refuge use in areas with high and low amounts of CWD. Our results suggest that CWD is important for the nesting ecology of cotton mice in southeastern pine forests, and increasing the amount of CWD may improve habitat quality for this species.

17 Liu, Yongqiang; Achtemeier, Gary; Goodrick, Scott. 2005. **Simulation and experiment of air quality effects of prescribed fires in the Southeast.** In: EastFIRE conference proceedings, 2005. Fairfax, VA: George Mason University: 1-4.

Wildfires can cause degradation of air quality by releasing large amounts of particulate matter (PM) and precursors of ozone. The EPA has issued the Interim Air Quality Policy on Wildland and Prescribed Fire to protect public health and welfare by mitigating the impacts of air pollutant emissions from wildland fires on air quality. Development and application of modeling tools for evaluating the impacts of wildland fires on air quality are needed to assist fire and smoke managers and policymakers in meeting air quality regulations and defining implementation plans.

18 Liu, Yongqiang; Qu, John J.; Hao, Xianjun; Wang, Wanting. 2005. **Improving fire emission estimates in the Eastern United States using satellite-based fuel loading factors.** In: EastFIRE conference proceedings, 2005. Fairfax, VA: George Mason University: 1-4.

Wildfires can lead to severe environmental consequences by releasing large amounts of particulate matter (PM) and precursors of ozone. The Southeast has the most burned area among various U.S. regions and has regionally some of the highest levels of PM and ozone in the Nation. Fires have been found to be an important contributor. On the other hand, smoke particles from wildfires are one of the atmospheric anthropogenic aerosol sources. They can affect global and regional radiation and climate.

19 McCarthy, Heather R.; Oren, Ram; Kim, Hyun-Seok. [and others]. 2006. **Interaction of ice storms and management practices on current carbon sequestration in forests with potential mitigation under future CO_2 atmosphere.** Journal of Geophysical Research. 111 (D15103): 1-10. [Editor's note: Station scientists Kurt H. Johnsen and Chris Maier co-authored this publication.]

(Photo by Zoë Hoyle, U.S. Forest Service)

Ice storms are disturbance events with potential impacts on carbon sequestration. Common forest management practices, such as fertilization and thinning, can change wood and stand properties and may change vulnerability to ice storm damage. At the same time, increasing atmospheric CO_2 levels may also influence ice storm vulnerability. Results in the Duke Forest case study suggest that forests may suffer less damage during each ice storm event of similar severity in a future with higher atmospheric CO_2.

20 Miller, Ashley T.; Allen, H. Lee; Maier, Chris A. 2006. **Quantifying the coarse-root biomass of intensively managed loblolly pine plantations.** Canadian Journal of Forest Research. 36: 12-22.

We assessed carbon accumulation in coarse roots of a loblolly pine plantation that was subjected to different levels of management intensity. Total belowground biomass was not affected by treatment. Vegetation control and disking increased pine taproot biomass and decreased hardwood taproot biomass. Pines between tree coarse roots were unaffected by treatment, but hardwoods between tree coarse roots were significantly reduced by vegetation control. Necromass was substantially lower than between-tree biomass, indicating decomposition of coarse-root biomass from the previous stand was rapid for between-tree coarse roots. Total aboveground biomass was increased by vegetation control, with highest production on most intensively managed plots. Coarse-root biomass ranged from 19 to 24 percent of total biomass. Silvicultural practices increasing aboveground pine productivity did not increase total coarse-root biomass carbon because of the difference in root/shoot allocation between pine and hardwood species.

21 Perry, Roger W.; Thill, Ronald E. 2007. **Roost characteristics of hoary bats in Arkansas.** American Midland Naturalist. 158: 132-138.

The hoary bat (*Lasiurus cinereus*) is the most widespread of all American bats, but little is known about its ecology, especially in the Eastern United States. Using radiotransmitters, we located 12 tree roosts during late spring and early summer in the Ouachita Mountains of central Arkansas. Hoary bats roosted about 16.5 m above the ground, generally on the easterly sides of tree canopies. Roosts were located in the foliage of white oaks (*Quercus alba*), post oaks (*Q. stellata*), and shortleaf pines (*Pinus echinata*), and all trees were >21 cm in diameter. All roosts were in forest stands dominated by mature (>50 years old) overstory trees, and included unmanaged mixed pine-hardwood and hardwood stands, stands that recently had been thinned and subjected to prescribed burning, and stands that were thinned approximately 10 years previously. Results indicate hoary bats reproduce in Arkansas and roost in the foliage of both mature pines and hardwoods.

22 Perry, Roger W.; Thill, Ronald E. 2007. **Roost selection by male and female northern long-eared bats in a pine-dominated landscape.** Forest Ecology and Management. 247: 220-226.

Roosts are critical to the survival of bats, but little information is available on roost selection by northern long-eared bats (*Myotis septentrionalis*) in pine-dominated forests of the Southeastern U.S. We used radiotransmitters to locate the summer daytime roosts of northern long-eared bats in forests of the Ouachita Mountains (Arkansas) to determine the types of roosts used, the habitats where those roosts were located, and how roosts differed between the sexes. Northern long-eared bats roosted mostly in dead trees (snags) where they concealed themselves in cavities, crevices, and under loose bark. Both sexes preferred shortleaf pine (Pinus echinata) snags over hardwood snags. Females roosted more in partially harvested or thinned forest stands than males and roosted in snags that were greater in diameter and surrounded by fewer midstory trees than males. Our results demonstrate the importance of maintaining pine snags for roosting by northern long-eared bats and the importance to females of snags located in relatively open forests.

23 Perry, Roger W.; Thill, Ronald E. 2007. **Tree roosting by male and female eastern pipistrelles in a forested landscape.** Journal of Mammalogy. 88(4): 974-981.

Although eastern pipistrelle bats (*Pipistrellus subflavus*) are abundant throughout the Eastern U.S., little is known about their roosting in forests. We radiotracked male and female eastern pipistrelles to their summer roosts to determine types of roosts used, habitats where those roosts were located, and how roosts differed between the sexes in mixed pine-hardwood forests of the Ouachita Mountains, Arkansas. All roosts were located in the foliage of tree canopies, and most were in dead leaves of deciduous trees. Most male roosts were in oaks (*Quercus* spp.), but females occasionally roosted in dead needles that had accumulated in the canopies of large live shortleaf pines (*Pinus echinata*). Males roosted in a wide variety of tree sizes, but females preferred larger trees. During the summer, eastern pipistrelles prefer to roost in the leaves of oaks, in forests older than 50 years that contain abundant midstory hardwoods.

24 Perry, Roger W.; Thill, Ronald E; Leslie, David M. 2007. **Selection of roosting habitat by forest bats in a diverse forested landscape.** Forest Ecology and Management. 238: 156-166.

During the day, forest bats roost in either the foliage of live trees or in the cavities and crevices of trees and snags. We studied effects of forest different conditions on roost selection by six species in the Ouachita Mountains of Arkansas. Five of six species preferred to roost in or near areas that had undergone recent partial tree harvest and prescribed burning. Five species preferred to roost in or near forests greater than 100 years old. In partially harvested areas, some bats roosted extensively in unharvested buffers that surrounded stream drains, whereas others rarely roosted in those buffers. Some species roosted mostly in pine-dominated stands, whereas others roosted mostly in hardwood-dominated stands. Our study demonstrates the importance of open forests and a diversity of forest conditions to bat communities in the Southeastern U.S.

25 Rudolph, D. Craig; Conner, Richard N.; Schaefer, Richard R.; Koerth, Nancy E. 2007. **Red-cockaded woodpecker foraging behavior.** Wilson Journal of Ornithology. 119(2): 170-180.

We studied red-cockaded woodpeckers (*Picoides borealis*) to examine the effect of status and gender on foraging behavior. Foraging behavior of breeding pairs extended beyond separation by foraging height to include zones (bole, trunk in crown, primary limb, secondary limb) of the tree used and foraging methods (scaling, probing, excavating). Helper males and juvenile females maintained partial spatial separation from breeding adults. Helper males maintained spatial separation from breeding adults by exploiting limbs within tree crowns in both longleaf (*Pinus palustris*) and loblolly-shortleaf (*P. taeda*, *P. echinata*) pine forests, but also increased use of boles in loblolly-shortleaf pine in concert with reduced use of boles by adult females. Breeding males tended to forage less by scaling, probably due to the reduced proportion of foraging on boles of trees where scaling tends to predominate.

26 Sampson, D.A.; Waring, R.H.; Maier, C.A. [and others]. 2006. **Fertilization effects on forest carbon storage and exchange, and net primary production: a new hybrid process model for stand management.** Forest Ecology and Management. 221: 91-109.

A critical ecological question in plantation management is whether fertilization, which generally increases yield, results in enhanced carbon sequestration over short rotations. We present a rotation-length hybrid process model (SECRETS-3PG) that was calibrated and verified, using daily estimates of H_2O and CO_2 fluxes, canopy leaf area index (L), and annual estimates of tree growth and dimension. We focus on two decades of loblolly pine (*Pinus taeda* L.) growth and establishment for stands growing on a nutrient poor, droughty soil in North Carolina, USA, on a site previously occupied by a ~30-year-old natural longleaf pine (*P. palustris* Mill.) stand. Seasonal patterns in net ecosystem productivity (NEP) suggest that autumn and winter may be critical periods for carbon uptake in nutrient-limited loblolly pine stands. We conclude that increased L in response to improved nutrition may enable loblolly pine to achieve positive annual NEP earlier in rotation.

27 Waldrop, Thomas A.; Brudnak, Lucy; Rideout-Hanzak, Sandra. 2007. **Fuels on disturbed and undisturbed sites in the Southern Appalachian Mountains, USA.** Canadian Journal of Forest Research. 37: 1134-1141.

Fire managers in the Southern Appalachians use limited direct measurements of fuels or best guesses of fuel loading to predict fire behavior and develop fire plans. Prediction of fuel loading can be as complex as the mountains themselves, because fuels may be closely associated with site quality and forest cover type. For this study we measured over 1000 plots across the Southern Appalachians to determine fuel loading by type across a range of combinations of aspect, slope position, and disturbance types. The numbers provided for fuel loading on undisturbed plots can be used directly for fire planning or fire behavior modeling with a fair degree of accuracy because of our large sample size, the low degree of variability among sample plots, and the widespread (four states) sampling design. The study provides insight to the degree, type, and topographic position of disturbances in the region.

forest values, uses, and policies

28 Abt, Karen L.; Prestemon, Jeffrey P. 2006. **Timber markets and fuel treatments in the Western U.S.** Natural Resource Modeling. 19(1): 15-43.

We developed a model of interrelated timber markets in the U.S. West to assess impacts of large-scale fuel reduction programs and concomitant effects on fuel reduction programs. The model allows interstate and international trade with western Canada and the rest of the world, while accounting for price effects of introducing softwood logs to the market. The model maximizes area treated, given fire regime-condition class priorities, maximum increases in softwood processing capacity, maximum rates of annual treatments, prohibitions on exports of U.S. and Canadian softwood logs from public lands, and a fixed annual treatment budget. Results show that the loss to U.S.

private timber producers is less than the gains for timber consumers (mills). States receiving more treatments when spending is not constrained by State proportions include Idaho, Montana, New Mexico and Oregon. When only the wildland-urban interface is treated, California, Oregon and Washington receive more treatments. Utah and Colorado receive more treatments when low risk stands are included.

29 Cook, Stephen; Cherry, Shane; Humes, Karen. [and others]. 2007. **Development of a satellite-based hazard rating system for *Dendroctonus frontalis* (Coleoptera: Scolytidae) in the Ouachita Mountains of Arkansas.** Journal of Economic Entomology. 100(2): 381-388. [Editor's note: Southern Station scientist Jim Guldin co-authored this publication.]

The southern pine beetle, *Dendroctonus frontalis* Zimmermann, is the most damaging forest insect pest of pines (*Pinus* spp.) throughout the Southeastern United States. Hazard rating schemes have been developed, but to be accurate and effective, these schemes require extensive on-site measurements of stand attributes such as host density, age, and basal area. We developed a stand hazard-rating scheme for several watersheds in the Ouachita Highlands of Arkansas based upon remotely sensed data and a geographic information system. A hazard model was developed and used to establish baseline maps. Landsat 7 ETM + data were used for developing new hazard maps. Although the models are specific for the study area, with modifications, they should be transferable to geographically similar areas.

30 Eberhardt, Thomas L.; Li, Xiaobo; Shupe, Todd F.; Hse, Chung Y. 2007. **Chinese tallow tree (*Sapium sebiferum*) utilization: characterization of extractives and cell wall chemistry.** Wood and Fiber Science. 39(2): 319-324.

Wood, bark, and the wax-coated seeds from Chinese tallow tree (*Sapium sebiferum* (L.) Roxb. syn. *Triadica sebifera* (L.) Small), an invasive tree species in the Southeastern United States, were subjected to extractions and degradative chemical analyses in an effort to better understand the mechanism(s) by which this tree species aggressively competes against native vegetation, and also to facilitate utilization efforts. Results suggest that Chinese tallow tree wood utilization, along with commercial wood species, should not present any significant processing problems related to the extractives or cell wall chemistry.

31 Eberhardt, Thomas L.; Reed, Karen G. 2006. **Strategies for improving the performance of plywood adhesive mix fillers from southern yellow pine bark.** Forest Products Journal. 56(10): 64-68.

Southern yellow pine bark was obtained from an industrial source and subjected to grinding and sieving operations to ultimately afford finely ground bark fractions for evaluation as plywood adhesive mix fillers; elimination of domestic filler supplies has created interest in finding alternatives. One of the fillers, prepared from a fraction rich in periderm tissue with its interlocking spiculate stone cells (sclereids), had superior performance over that prepared directly from the bark as received. This appears to be related to the removal of extractive-rich bark components that likely promote resin undercure. Since high ash contents cause excessive tool wear during subsequent cutting operations, the significantly lower ash content of this filler is also beneficial.

32 Gallagher, T.; Shaffer, B.; Rummer, B. 2006. **An economic analysis of hardwood fiber production on dryland irrigated sites in the U.S. Southeast.** Biomass and Bioenergy. 30(8-9): 794-802.

Although there is renewed interest in intensively managed, short-rotation plantations as a source of hardwood for pulp mills, few have been established in the Southeast. Understanding all the costs associated with these plantations will help determine their feasibility. Using a model developed to summarize all the costs, a break-even analysis was completed to determine the delivered cost for plantations of eastern cottonwood (*Populus deltoides* Bartr.) from a hypothetical fiber farm in 2003. Using current yield from an experimental fiber farm, short-rotation cottonwood plantations were not cost effective, as delivered cost to a pulp mill averaged 78t^{-1}. If yield can be increased by 40 percent through improvements in genetics and silvicultural practices, delivered cost is reduced to 60t^{-1}. Thus,

Tree root studies often require extensive digging and cleaning. (Photo by Chris Maier, U.S. Forest Service)

finding this additional yield is key to the cost feasibility of intensively managed, short-rotation hardwood plantations.

33 Gao, Heng; Shupe, Todd F.; Eberhardt, Thomas L.; Hse, Chung Y. 2007. **Antioxidant activity of extracts from the wood and bark of Port Orford cedar.** Journal of Wood Science. 53: 147-152.

The antioxidant activities of chemicals present in Port-Orford cedar (*Chamaecyparis lawsoniana* (A. Murray) Parl.) heartwood, sapwood, inner bark, and outer bark were determined by assaying extracts isolated from each tissue for the capacity to scavenge free radicals. These assays, coupled with determinations of total phenol content, showed a positive correlation between antioxidant activity and the presence of phenolic compounds. The inner bark possessed both the highest antioxidant activity and total phenol content. Therefore, this tissue appears to be the preferred source of antioxidants from this tree species. Given the generation of free radicals during wood decay, an alternative application for these biomass-derived antioxidants may be wood preservation.

34 Johnson, Cassandra; English, D.B.K. 2007. **Visitor diversity on national forests—how should managers respond?** In: Kruger, Linda E.; Mazza, Rhonda; Lawrence, Kelly, eds. Proceedings: national workshop on recreation research and management. Gen. Tech. Rep. PNW-GTR-698. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 57-60.

We examine differences in proportion of visits to nature-based outdoor recreation areas in the United States by Anglo Americans, Asian Americans, Hispanics, and African Americans. We report on differences in types of activities in which groups engage; e.g., African Americans and Hispanics tend to emphasize collective, family-oriented activities, while Anglo recreation traditionally involves more individualistic, dispersed activities. Demographic changes along cultural and ethnic lines are causing managers to reconsider the way they manage natural resources and types of amenities they offer. Managers need to know how to effectively communicate with groups whose first language is not English. A consideration for managers in the South is how to more effectively engage African Americans in forest-based outdoor recreation and how to assess their interests and constraints, comparing those with offerings on national forests.

35 Johnson, Cassandra Y.; Bowker, J.; Green, Gary; Cordell, H. 2007. **"Provide it . . . but will they come?" A look at African American and Hispanic visits to Federal recreation areas.** Journal of Forestry. 105(5): 257-265.

Estimates from the National Visitor Use Monitoring Survey show that visits made by African Americans account for very low percentages of visits to national forests across the country, even in the South, where African Americans are highly concentrated. In contrast, visits by Hispanics to national forests in the Southwest are more reflective of their population proportions in that region. These regional differences indicate the need for closer attention to factors that might inhibit African American use of wildland public recreation areas in the South.

36 Kilgore, Michael A.; Greene, John L.; Jacobsen, Michael G. [and others]. 2007. **The influence of financial incentive programs in promoting sustainable forestry on the Nation's family forests.** Journal of Forestry. 105(4): 184-191.

Financial incentive programs were evaluated to assess their contribution to promoting sustainable forestry practices on the Nation's family forests. The evaluation consisted of an extensive review of the literature on financial incentive programs, a mail survey of the lead administrator of financial incentive programs in each State forestry agency, and focus groups with family forest owners in four regions of the country. The study found that financial incentive programs have limited influence on forest owners' decisions regarding the management and use of their land. Family forest owners viewed one-on-one access to a forester or other natural resource professional to "walk the land" with them and discuss their management alternatives as the most important type of assistance

Ramps. (U.S. Forest Service photo)

Loblolly pine in Dare County, NC. (Photo by Paul Bolstad, University of Minnesota, www.bugwood.org)

that can be provided. Recommendations for increasing the effectiveness of financial incentive programs in promoting sustainable forestry are discussed.

37 Monroe, Martha C.; McDonell, Lauren; Hermansen-Báez, L. Annie. [and others]. 2007. **Building successful partnerships for technology transfer.** Journal of Extension. 45(3): 1-5. [Editor's note: Station scientist Wayne Zipperer co-authored this publication.]

As budgets for Cooperative Extension projects get tighter, many units are enticed to consider partnerships with agencies and organizations to continue to proactively deliver services. Our experience working in a partnership between the University of Florida and the U.S. Forest Service that involves joint staffing and funding for technology transfer and research projects enables us to offer specific advice on how to use this tool most effectively. Communication and planning are essential and should cover everything from who gets office keys to who hires temporary staff.

38 Via, Brian K.; So, Chi L.; Groom, Leslie H. [and others]. 2007. **Within tree variation of lignin, extractives, and microfibril angle coupled with the theoretical and near infrared modeling of microfibril angle.** IAWA Journal. 28(2): 189-209.

Characterization of wood microfibril angle (MFA) is important when predicting wood stiffness. In recent years, research has focused on validating the ability of using near infrared spectroscopy (NIR) to rapidly predict MFA. To date, most research has been empirically based, with no data or theoretical explanation for how NIR spectra can be used to predict MFA. The main benefit of this research was that it found MFA, lignin content, and NIR spectra to co-vary. Both theoretical and statistical models were developed to validate the three-way relationship between lignin, MFA, and near infrared spectra. Lignin content was found to be a primary factor responsible for prediction of MFA from NIR spectra. Future research is needed to further partition factors responsible for NIR accuracy and precision when predicting MFA.

threats to forest health

39 Joyce, Linda; Aber, John; McNulty, Steve [and others]. 2001. **Potential consequences of climate variability and change for the forests of the United States.** In: National Assessment Synthesis Team, eds. Climate change impacts on the United States. Cambridge, England: Cambridge University Press: 489-524. Chapter 17.

Forests cover nearly one-third of the U.S., providing wildlife habitat, clean air and water, cultural and aesthetic values, carbon storage, recreational opportunities such as hiking, camping, fishing, and autumn leaf tours, and products that can be harvested such as timber, pulpwood, fuel wood, wild game, ferns, mushrooms, and berries. This wealth depends on forest biodiversity—the variety of plants, animals, and microbe species, and forest functioning—water flow, nutrient cycling, and productivity. These aspects of forests are strongly influenced by climate and human land use.

40 Riitters, Kurt H.; Vogt, Peter; Soille, Pierre. [and others]. 2007. **Neutral model analysis of landscape patterns from mathematical morphology.** Landscape Ecology. 22: 1033-1043.

Previous national assessments of forest fragmentation identified the need for better indicators of fragmentation and more efficient computational approaches. Recent research has developed protocols based on morphological image processing. This paper uses a neutral model approach to lay the foundation for applying those protocols in the U.S. Forest Service 2010 national RPA Assessment required by the Resource Planning Act. This paper also reports the discovery of a new type of "pattern phase change" on random binary maps, presently of theoretical interest but which may have real-world implications for organism movement and species persistence in a landscape.

41 Schomaker, Michael E.; Zarnoch, Stanley J.; Bechtold, William A. [and others]. 2007. **Crown-condition classification: a guide to data collection and analysis.** Gen. Tech. Rep. SRS-102. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 78 p. [Editor's note: Station scientist William G. Burkman co-authored this publication.]

The Forest Inventory and Analysis (FIA) Program of the Forest Service, U.S. Department of Agriculture, conducts a national inventory of forests across the United States. A systematic subset of permanent inventory plots in 38 States is sampled every year for numerous forest health indicators. One indicator, crown-condition classification, is designed to estimate tree crown dimensions and assess the impact of crown stressors. The indicator features eight tree-level field measurements in addition to variables traditionally measured in conjunction with FIA inventories: vigor class, uncompacted live crown ratio, crown light exposure, crown position, crown density, crown dieback, foliage transparency, and crown diameter. Indicators of crown health are intended for analyses at State, regional, and national levels, and contribute to core tabular output in standard FIA reports. This report describes the data collection and analytical techniques recommended for crown-condition classification.

42 Ulyshen, Michael E.; Miller, Douglass R. 2007. **First record of *Acizzia jamatonica* (Hemiptera: Psyllidae) in North America: Friend or foe?** Florida Entomologist. 90(3): 573.

Acizzia jamatonica (Kuwayama) (Hemiptera: Sternorrhyncha: Psyllidae) is reported for the first time in North America. This species is thought to feed exclusively on Albizia and may prove to be an effective biocontrol agent against mimosa (*Albizia julibrissin* Durazzini) in the Southeastern United States. Because mimosa is also an ornamental plant of some importance, the arrival of A. jamatonica may not be welcomed by everyone. This is the fourth invasive species of *Acizzia* to be found in the United States.

43 Wade, Dale; Mobley, Hugh. 2007. **Managing smoke at the wildland-urban interface.** GTR SRS-103. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 28 p.

When prescribed burning is conducted at the wildland-urban interface (WUI), the resulting smoke can inconvenience people and also cause more serious health and safety problems. The public is unlikely to continue to tolerate the use of prescribed fire if burn managers cannot keep smoke out of smoke-sensitive areas. In the South, forest management organizations commonly require that plans for prescribed burns pass a smoke screening review, and some States require a review before authorizing a burn. Current screening systems, however, do not incorporate criteria for use at the WUI. This guide describes modifications to the Southern Smoke Screening System for burns at the WUI. These modifications couple new research findings with experience of burners who have extensively used the 1976 Southern Smoke Screening System. The new system is designed for use on burns less than 50 acres in size. It has undergone several years of successful field testing in Florida.

watershed science

44 Adams, Susan B. 2007. **Direct and indirect effects of channel catfish (*Ictalurus punctatus*) on native crayfishes (Cambaridae) in experimental tanks.** American Midland Naturalist. 158: 85-96.

Certain fish species prey heavily on crayfish. In north-central Mississippi, USA, streambeds are sand or clay, and hiding shelter for crayfish is limited. Therefore, fish predation may contribute to lower crayfish catches in larger streams compared to smaller streams. I conducted two experiments to test how shelter influenced channel catfish predation on a large and a small crayfish species. In outdoor tanks with catfish, the large crayfish species survived better than the smaller species. Shelter increased survival of the small species, but did not influence survival of the large species. Catfish also influenced the size of crayfish during the experiment, probably by reducing crayfish growth.

Weather gauge, Santee Experimental Forest. (Photo by Wade Spees)

45 Devall, Margaret S.; Smith, Geoffrey C. 2007. **Forests in the balance: linking tradition and technology in landscape mosaics.** Biological Conservation. 137: 487-488.

This special issue of *Biological Conservation* is based on papers presented at two technical sessions of the XXII IUFRO (International Union of Forest Research Organizations) World Congress held in Brisbane, Australia in August 2005. Forests around the world face many challenges from a variety of sources. This special issue attempts to bridge the gap between timber production and wildlife conservation and to move towards an integrated approach for developing a forest conservation strategy. The volume brings together information on the silviculture and management of rare tree species and promotes integrated management approaches that allow both production and biodiversity to be conserved in forest landscape mosaics. We hope the approaches discussed here will be implemented and help to advance forest production, as well as enhance biodiversity values.

46 Elliott, Katherine J.; Vose, James M. 2005. **Effects of understory prescribed burning on shortleaf pine (*Pinus echinata* Mill.)/mixed-hardwood forests.** Journal of Torrey Botanical Society. 132(2): 236-251.

We examined effects of a single dormant season fire on overstory and understory species diversity and composition and tree seedling regeneration patterns the first and second years following a prescribed burn in the Conasauga River watershed of southeastern Tennessee and northern Georgia. We asked: Can a single dormant season fire initiate a trajectory of overstory and understory species change consistent with restoring *Pinus echinata*/mixed-oak/bluestem (*Andropogon gyrans* and *Schizachyrium scoparium*)-grass community types? We studied six sub-watersheds (similar in vegetation, soil type, stream size, and disturbance history). Consistent with goals of land managers, all prescribed fires resulted in low-to-moderate intensity and low severity fires. We found no significant change in overstory, midstory, or ground flora species diversity after burning. Density of Pinus strobus, an undesirable species, was reduced by 20 percent, and basal area was reduced by 50 percent. The prescribed fires were not of sufficient intensity to reduce overstory basal area, prepare a seedbed for successful pine germination, affect diversity of any vegetation layers, or promote A. gyrans and S. scoparium recruitment. Additional fire treatments or combination of fire and thinning treatments will be necessary to restore these ecosystems to *P. echinata*/mixed-oak/bluestem grass community types.

47 Fairchilds, Lindsay H.; Trettin, Carl C. 2006. **History and legacy of fire effects in the South Carolina Piedmont and coastal regions.** Gen. Tech. Rep. SRS-98. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 27 p.

Agriculture, fire suppression, and urbanization have drastically altered natural forest processes and conditions in the Southeastern United States. Many of South Carolina's forests are dense and overstocked, with high fuel loads. These conditions increase susceptibility to southern pine beetle attack and wildfire. Threats are further complicated by rapid urbanization and forest fragmentation, processes that are increasing South Carolina's wildland-urban interface rapidly. Prescribed fire is an effective, economical, and widely used tool for reducing fuel loads and encouraging desired vegetative communities in forest landscapes. We considered fire effects on soil erosion, nutrients, and vegetation from a historical perspective. We examined fire regimes, land use changes, and fire research. Knowledge of past land use and fire's biological and historical roles in land use change can support effective decision making. This information will provide guidance for sustainable management of forest resources and reduction of hazardous forest fuel conditions.

48 Johnson, Jane M-F; Coleman, Mark D.; Gesch, Russ. [and others]. 2007. **Biomass-bioenergy crops in the United States: a changing paradigm.** The Americas Journal of Plant Science and Biotechnology. 1(1): 1-28.

The world energy paradigm is changing from one based on petroleum to one based on a mixture of energy platforms. This change is precipitated by a finite petroleum supply, expanding global demand, and political instability in areas with major petroleum reserves. The mixed energy platform will include an array of renewable energy sources. The agricultural and forestry sectors have the potential to provide several plant-based products. Emerging specialty crops have potential to supply feedstock as well. Altering fundamental aspects of plant growth, development, and responses to biotic and abiotic stresses and the opportunities to increase productivity and conversion-process efficiencies are strategies to expand biomass availability and usage. As the energy paradigm shifts, the balance among competing needs will be critical to achieve sustainable food, fiber, and energy while protecting the soil resource and the environment. This emphasizes avoiding potential negative environmental consequences of new bioenergy technologies and presents strategies on how this may be achieved.

49 Latham, Rebecca S.; Wooten, Richard M.; Witt, Anne C. [and others]. 2007. **Big slow movers: a look at weathered-rock slides in western North Carolina.** In: Proceedings, 1st North American Landslide Conference. Denver, CO: Association of Environmental and Engineering Geologists: AEG Special Publication No. 23: 545-557. [Editor's note: Station scientist Barton D. Clinton co-authored this publication.]

The North Carolina Geological Survey is implementing a landslide hazard-mapping program in western North Carolina. By December 2006, over 2700 landslides and landslide deposits had been documented. [The number has grown to over 4,500 as of October 2007.] A small number of these landslides are relatively large, slow-moving, weathered-rock slides, termed "big, slow movers" (BSMs). BSMs appear to have geomorphic and geologic settings similar to each other, and are often difficult to recognize without detailed field investigations. This paper describes three BSMs: the Toxaway River slide in Transylvania County; the 0.5-acre BSM at

the Lake Logan Center, located southeast of Waynesville in Haywood County; and a 1.5-acre BSM impacting homes in the Hunters Crossing subdivision, located just outside the Waynesville city limits.

50 Love, Jason P.; Vose, James M.; Elliott, Katherine J. 2007. **Effects of restoration burns on macroinvertebrates in Southern Appalachian pine-oak forests.** Journal of North Carolina Academy of Science. 123(1): 22-34.

Cover board arrays were used to measure relative abundance of macroinvertebrates and terrestrial salamanders on prescribed burn and control sites in xeric Southern Appalachians of northern Georgia and southeastern Tennessee pine-oak forests. Three microsite variables were measured at each cover board: cover board moisture level, temperature under the cover board, and soil moisture. Soil moisture was significantly higher on burn sites than controls after prescribed fire. Two groups of macroinvertebrates, Homoptera and Hymenoptera, were more abundant on burn sites than control sites. Coleoptera and Stylommatophora were significantly more abundant in riparian and low slope positions than upland positions, whereas other macroinvertebrate groups were not significantly related to slope position. Thirteen salamanders were found during four sampling periods. Overall, there was little evidence of negative post-fire impacts on macroinvertebrates or salamanders.

51 Roghair, Craig N.; Dolloff, C. Andrew. 2005. **Brook trout movement during and after recolonization of a naturally defaunated stream reach.** North American Journal of Fisheries Management. 25: 777-784.

In June 1995 a massive streamwide flood completely eliminated brook trout from 1.2 miles of the Staunton River in Shenandoah National Park, VA. Brook trout completely recolonized the reach within 3 years. This observation prompted the establishment of post-recolonization movement studies using two techniques: (1) mark-recapture and (2) radio telemetry. Both studies showed average fish movements of less than 0.10 miles, but the maximum detected movement was nearly 1.25 miles. Observed movements were consistent with those that were the basis for recolonization of the damaged reach. Understanding the ability of movement to affect population changes is necessary for proper management in the wake of catastrophic events.

52 Skojac, Daniel A., Jr.; Bryson, Charles T.; Walker, Charles H., II. 2007. **Noteworthy collections from the Yazoo-Mississippi Delta region of Mississippi.** Journal of the Botanical Research Institute of Texas. 1(1): 769-775.

The flora of the Yazoo-Mississippi Delta region is poorly known compared to the rest of Mississippi or adjoining States. Fifteen species are reported new to the Yazoo-Mississippi Delta region, and significant range extensions are provided for five additional species. Of these, four are invasive weeds, including water hyacinth, a Federal noxious weed. Three species are on the special concern list of rare plants in Mississippi.

Water depth gauge, Santee Experimental Forest. (Photo by Wade Spees)

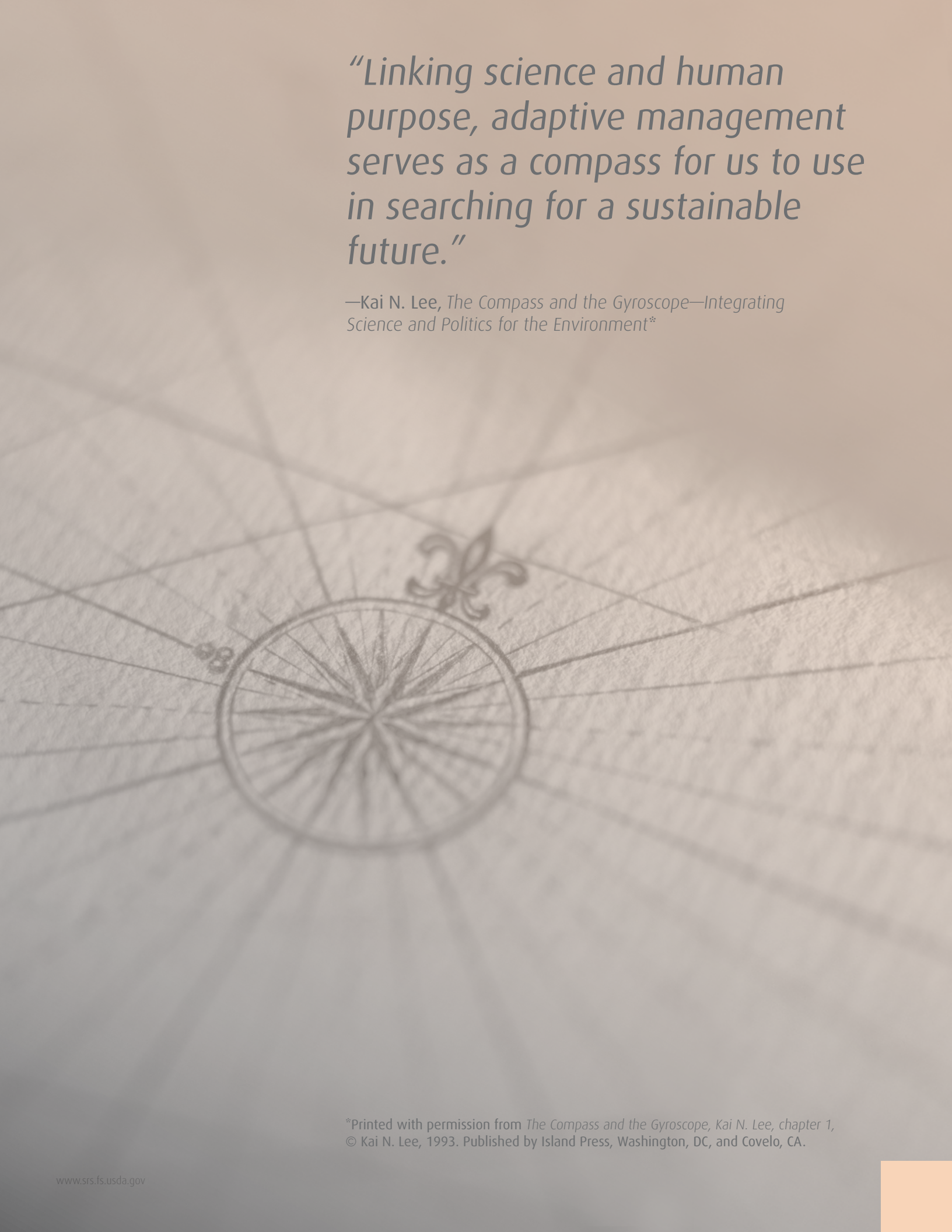
(Photo by Rodney Kindlund, U.S. Forest Service)

Research Work Units

Location & Project Leader	Name & Web Site	Phone
Athens, GA Ken Cordell	Pioneering Forestry Research on Emerging Societal Changes	706-559-4263
Forest Ecosystem Restoration and Management		
Asheville, NC Cathryn Greenberg	Upland Hardwood Ecology and Management www.srs.fs.usda.gov/bentcreek	828-667-5261
Auburn, AL Kris Connor	Restoring and Managing Longleaf Pine Ecosystems www.srs.fs.usda.gov/4111	334-826-8700
Monticello, AR James Guldin	Southern Pine Ecology and Management www.srs.fs.usda.gov/4106	870-367-3464
Saucier, MS Dana Nelson	Forest Genetics and Ecosystems Biology www.srs.fs.usda.gov/organization/unit/mississippi.htm#SRS-4153	228-832-2747
Forest Values, Uses, and Policies		
Athens, GA Vacant	Integrating Human and Natural Systems www.srs.fs.usda.gov/trends	706-559-4222
Auburn, AL Bob Rummer	Forest Operations www.srs.fs.usda.gov/forestops/	334-826-8700
Pineville, LA Les Groom	Utilization of Southern Forest Resources www.srs.fs.usda.gov/4701	318-473-7268
Research Triangle Park, NC David Wear	Forest Economics and Policy www.srs.fs.usda.gov/econ	919-549-4093
Threats to Forest Health		
Asheville, NC Danny Lee	Eastern Forest Environmental Threat Assessment Center www.srs.fs.usda.gov/cc/threatassessment.htm	828-257-4854
Athens, GA John Stanturf	Center for Forest Disturbance Science www.srs.fs.usda.gov/disturbance	706-559-4316
Pineville, LA Kier Klepzig	Insects, Diseases, and Invasive Plants of Southern Forests www.srs.fs.usda.gov/4501	318-473-7232
Forest Watershed Science		
Franklin, NC Jim Vose	Center for Forest Watershed Research www.srs.fs.usda.gov/coweeta	828-524-2128
Lincoln, NE Michele Schoeneberger	National Agroforestry Center - Research www.nac.gov	402-437-5178
Stoneville, MS Ted Leininger	Center for Bottomland Hardwoods Research www.srs.fs.usda.gov/cbhr	662-686-3154
Natural Resources Inventory and Monitoring		
Knoxville, TN Bill Burkman	Forest Inventory and Analysis www.srsfia2.fs.fed.us	865-862-2000

"Linking science and human purpose, adaptive management serves as a compass for us to use in searching for a sustainable future."

—Kai N. Lee, *The Compass and the Gyroscope—Integrating Science and Politics for the Environment**



*Printed with permission from *The Compass and the Gyroscope, Kai N. Lee, chapter 1,* © Kai N. Lee, 1993. Published by Island Press, Washington, DC, and Covelo, CA.

COMPASS

Science You Can Use!

U.S. Forest Service
Southern Research Station
Science Delivery Office
200 W.T. Weaver Boulevard
Asheville, NC 28804-3454 USA

Address Correction Requested

OFFICIAL BUSINESS
Penalty for Private Use $300

visit our Web site at: www.srs.fs.usda.gov

Next Issue...

American chestnut trees still live in Southeastern forests, but most are small, mere echoes of the giants that once fed wildlife and livestock and provided that famous spreading shade for farmhouses and city streets alike. In the early 20th century, an estimated 3.5 billion American chestnut trees were killed by a lethal fungus known as chestnut blight, and Southern forests transformed by the disturbance.

A quarter of a century ago, in 1983, a group of plant scientists founded The American Chestnut Foundation (TACF) to look into breeding blight resistant American chestnut trees. 2008 marks the 25th anniversary for TACF, and they've partnered with the Forest Service to begin planting and testing blight-resistant hybrids on six sites from Tennessee to West Virginia. In the next issue of Compass, we'll look at how SRS research is contributing to this revival of the "Sequoia of the East."

STD PRSRT
US POSTAGE
PAID
USDA, FS
PERMIT NO. G-40

Seed burr from American Chestnut (Photo by Paul Wray, Iowa State University, www.bugwood.org)