COMPASS

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

issue 13

Celebrating the experimental forests in the South.....

Reviving Upland Hardwood Forests...page 3
Water for the South...page 13
The Return of Longleaf Pine...page 25

inside... the science

1 **Experimental Forests in the South Come of Age—Again**
by Jim Guldin

No other region has relied more on their experimental forests to provide the information needed to support public and private forest management than the South.

3 **Reviving Upland Hardwood Forests**
by Stevin Westcott

3 **Bent Creek**—*The East's first experimental forest*

9 **The Sylamore**—*The role of fire in the Interior Highlands*

10 **The Koen**—*Upland hardwood field research in Arkansas*

11 **Blue Valley**—*The ecology of eastern white pine*

13 **Water for the South**
by Gary Kuhlmann

13 **Coweeta**—*Long-term data for today's problems*

16 **The Santee**—*Heading off threats to water supply and quality*

18 **Alum Creek**—*Hydrologic studies in the Interior Highlands renewed*

20 **The Delta**—*From bottomland hardwood restoration to food for the "lord god" bird*

22 **The Tallahatchie**—*Tornadoes create new research opportunities*

25 **The Return of Longleaf Pine**
by Zoë Hoyle

26 **The Escambia**—*A living laboratory for longleaf pine regeneration*

31 **The Palustris**—*What if natural regeneration isn't an option*

35 **The Harrison**—*Longleaf genetics come of age*

36 **The Chipola**—*A unique sandhill site*

37 **Bringing Productive Pine Forests to Ruined Land**
by Carol Whitlock

38 **The Crossett**—*Regrowth starts in the West*

40 **The Harrison**—*Seed for reestablishing southern pine forests*

41 **The Stephen F. Austin**—*Productivity is more than just trees*

42 **The Calhoun**—*Restoring soil on wasted lands*

45 **The Hitchiti**—*Demonstrating the effects of prescribed burning*

47 **The Olustee**—*From naval stores to southern pine genetics*

48 **Scull Shoals**

departments

New Products 50
Research Work Units 62

briefs

Southern Experimental Forests (by year of establishment) 2
Margaret Stoughton Abell 5
Tracking Recreation at Bent Creek 8
Forty Acres: Making it work for landowners 29
Longleaf Pine Seed Problems 30
Containers, Copper, and Roots 33
Why Termites? 43

Cover photo: Established in 1947 on the Escambia Experimental Forest, the Farm Forty Study was designed to show landowners what they could get off 40 acres of longleaf pine in a year. In 2009, the Escambia held its first Farm Forty Field Day in over 40 years.

COMPASS

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perspectives and tools to benefit southern forest resources

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In the 1930s, in stark contrast to what we see today, millions of acres of land consisted of cutover forest or abandoned farmland mostly denuded of trees. In the early years, research on the experimental forests featured in this issue focused on developing the knowledge to reforest and rehabilitate national forests and privately owned lands in the East. (Forest Service photo)

Experimental Forests in the South Come of Age—Again

by Jim Guldin

The year 2008 marked the 100th anniversary of the establishment of the network of **Forest Service Experimental Forests and Ranges** in the United States. In 2009, the Southern Research Station (SRS) will hold 75th anniversary celebrations for the **Coweeta Hydrologic Laboratory** and **Crossett Experimental Forest**. The **Bent Creek Experimental Forest** celebrated over 80 years in 2008.

Sites for the experimental forests and ranges were originally chosen to reflect a range of ecosystems, and to foster the research needed to rehabilitate the cutover forests and ruined land that covered much of the South. These outdoor laboratories support an astonishing record of research in forest ecology and silviculture, hydrology and watershed management, forest economics, and forest products. They are treasured scientific assets for our Nation. Today we are challenged to not only continue the important long-term research they contain, but also to use this stellar network to develop answers to new problems at the landscape and regional levels.

Out of Desolation, Restoration

There is no region of the country that has relied more on these resources to support public and private forest management than the South. All of the 19 active southern experimental forests have been uniquely important in one way or another, materially advancing what we know scientifically and in application to public and private lands. For example, hydrological studies at Coweeta in North Carolina, the Santee in South Carolina, the Tallahatchie in Mississippi, and the Alum Creek and Koen in Arkansas have provided the scientific basis for our understanding of upland forest hydrology, the role forests play in maintaining water quality, and the management techniques needed to maintain terrestrial and aquatic forest ecosystems.

> **Experimental forests are the very backbone of Forest Service research, providing the long-term data needed to answer current questions.**

The recovery of southern pine forests after the timbering era was made possible through silvicultural research in Coastal Plain loblolly-shortleaf pine at the Crossett in Arkansas, in Piedmont loblolly pine on the Hitchiti in Georgia, in longleaf pine on the Escambia in Alabama, and in slash pine at the Olustee in Florida. The foundation of artificial regeneration in southern pines was built from genetics and physiology research on the Harrison in Mississippi, and from direct seeding and planting research on the Palustris in Louisiana. These advances collectively have made southern forests the "Wood Basket of the Nation."

Restoration of degraded Piedmont landscapes was made possible with soil restoration research on the Calhoun in South Carolina, whose site, when founded, was referred to as the "worst of the worst." Research studies on Appalachian oak-hickory stands at Bent Creek in North Carolina, on Ozark oak-hickory stands at the Sylamore in Arkansas, and in bottomland hardwood stands at the Delta in Mississippi, have been of utmost importance to the recovery and management of the diverse and productive hardwood forests of the region. Finally, research at the Stephen F. Austin in Texas was important in helping to understand the ecology and management of white-tailed deer and later, a range of threatened and endangered wildlife species.

Widening the Lens

As society's appreciation of forests has changed, so has the research on the experimental forests, which were first set up to help solve relatively local problems. Today, this network of research sites is increasingly seen as important in the context of regional problems. Southern experimental forests are the repository of important long-term research that serves as a benchmark for ecosystem development and forest stability, with a number of unique climate, water, and vegetation datasets that exceed 70 years of continuous measurement. This is in no small measure due to the simple fact that the Federal land base is stable in comparison with privately owned lands, where ownership changes can mean the end of experiments.

(continued on page 2)

Experimental Forests Come of Age

(continued from page 1)

Their reputation as holy places of forestry research has made a handful of SRS experimental forests such as Bent Creek, Coweeta, Crossett, and Hitchiti extraordinarily important in the realm of education and demonstration. Field days, continuing education workshops, and short courses have all been used on these sites to translate the dry findings of scientific journal articles into a reality that can in some cases only be fully appreciated with boots on the ground. There are few better ways to grasp the importance of forest health, diversity, productivity, or sustainability than experiencing one of these iconic sites in person.

But there is a broader need in relation to regional and national scientific problems. Scattered as they are across the South, the SRS experimental forests represent a gradient of scientific opportunity to address 21st century issues such as climate change, natural and human-produced disturbance, urban encroachment, and ecosystem fragmentation. Drawing on models of 20th century scientific accomplishment such as the Coweeta Long-Term Ecological Research Program, recent national initiatives such as common weather stations and the development of ecological observatory networks, the experimental forests managed by SRS promise to be equally important in the forest science of the 21st century and beyond.

Jim Guldin is project leader for the SRS Southern Pine Ecology and Management unit based in Monticello, AR.

An early photograph (circa late 1930s) of the office facilities on the Crossett Experimental Forest. (Forest Service photo by Russ Reynolds)

Southern Experimental Forests
(by year of establishment)

Year established	Name and location	Research emphasis	page
1925	Bent Creek, NC	Hardwood regeneration, Southern Appalachians	3
1931	Olustee, FL	Naval stores, genetic improvement of southern pines, slash pine	47
1934	Coweeta, NC	Foundation for basic concepts of forest hydrology	13
1934	Crossett, AR	Coastal Plain loblolly-shortleaf pine silviculture	38
1934	Harrison, MS	Pine seed source study, genetics, termiticide testing	35, 40
1934	Sylamore, AR	Upland hardwood studies, Ozarks	9
1935	Palustris, LA	Growth models for southern pines, longleaf pine seed, and containers	31
1937	Santee, SC	Coastal Plain forest hydrology	16
1945	Delta, MS	Bottomland hardwoods, insect control	20
1945	Stephen F. Austin, TX	White-tailed deer, threatened and endangered wildlife species	41
1946	Hitchiti, GA	Piedmont loblolly pine management, prescribed burning	45
1947	Calhoun, SC	Long-term soil restoration, termiticide testing	42
1947	Escambia, AL	Natural regeneration of longleaf pine	26
1950	Koen, AR	Forest hydrology, upland hardwoods, Interior Highlands	10
1950	Tallahatchie, MS	Forest hydrology, 2008 tornado damage	22
1952	Chipola, FL	Choctawhatchee sand pine, termiticide testing	36
Late 1950s	Alum Creek, AR	Forest hydrology, Interior Highlands	18
1959	Scull Shoals, GA	Hardwood regeneration, pine littleleaf disease	48
1964	Blue Valley, NC	Eastern white pine-hardwood stands	11

Reviving Upland Hardwood Forests

Bent Creek

The East's first experimental forest

by Stevin Westcott

In 2009, the Forest Service celebrates the 100th anniversary of the experimental forests and ranges set up across the Nation to conduct ecological research, make discoveries, and demonstrate research results. SRS manages 19 of these 81 living laboratories and natural treasures that, for decades, have provided a wide variety of benefits, ranging from clean water to recreational opportunities. We mark the centennial by celebrating the sound science that provides foresters, landowners, and many others the knowledge needed to better manage the Nation's forests and rangelands. Such a celebration would be incomplete without special recognition of the first experimental forest east of the Mississippi and the third oldest in the Nation—the **Bent Creek Experimental Forest** (Bent Creek).

Establishing the Laboratory

After World War I, the Forest Service sought to establish an experimental station on a site that represented the diversity of the Southern Appalachian Mountains. The Bent Creek area of western North Carolina was a logical choice. Named for a bend in the creek near the French Broad River, the Bent Creek area typified the upland hardwood forests that spread across much of the region. Bent Creek's timber stands were rich in oak, chestnut, hickory, yellow-poplar, and pine. During European settlement, the mountain region supported stands of timber that averaged between 10 to 15 thousand—sometimes 40 thousand—board feet per acre. Deer, bear, turkey, and other wildlife called the region home.

Located just outside Asheville, NC, the largest city in that part of the State, Bent Creek was well positioned to serve as a meeting and demonstration site for researchers, foresters, and many others. In 1925, the Forest Service established the area that officially became the Bent Creek Experimental Forest. This was 4 years after the Agency established the **Appalachian Forest Experiment Station** (AFES), the facility that would manage Bent Creek and other experimental forests in the Southeast, in Asheville.

Bent Creek was, in some ways, a product of the new conservation and forest science movement that emerged in western North Carolina in the mid-to-late 19th century. This conservation movement, in large part, was a response to the unsustainable timber harvesting practices, overgrazing, and other poor land management practices of the late 19th and early 20th centuries that left large portions of Southern Appalachia and elsewhere in desperate need of rehabilitation and regeneration. In the late 1800s, **Carl Schenck** and others started the Nation's first forestry school on land near Bent Creek that was owned by George Vanderbilt, who had a great interest in science—specifically horticulture and silviculture.

The Forest Service established Bent Creek to conduct research on forest regeneration, erosion control, and to demonstrate forest management practices. In 1925, with financial assistance from the Federal Bureau of Entomology, the Agency set aside 150 acres on the **Pisgah National Forest**, which consisted of land purchased by the Forest Service from Vanderbilt's estate, for the new research facility. In 1927, the Forest Service expanded the experimental forest from 150 to 1,100 acres. In 1935, the Agency shifted another 5,200 acres of the Pisgah to Bent Creek, bringing the acreage to about 6,300. In the 1940s and 1960s, portions of the experimental forest were removed for recreational use and for a major road project, bringing the total to about 5,500 acres today.

Construction continued into the early 1930s as the Civilian Conservation Corps, a New Deal work relief program for young men from unemployed families, built the 4-mile Hardtimes Road that still winds through the experimental forest. At the same time, other New Deal workers constructed 13 buildings including

(continued on page 4)

Bent Creek

(continued from page 3)

4 laboratories, a bunkhouse, 2 garages, a ranger's house, and an insectory. These now rustic buildings were built with handhewn chestnut beams and white oak shingles. Nearly all of Bent Creek's original buildings still stand today.

Early Research

Earl H. Frothingham, the first director of AFES, played an important role in establishing Bent Creek and guided its research early on.

"Frothingham's goal was to provide a place to begin a program of silvicultural research in the Southern Appalachians," says **David Loftis**, research forester and former project leader at Bent Creek, "and to bring a fairly large area under management so we could observe problems and then demonstrate results. We've tried to fulfill those objectives over the years."

Frothingham focused early research at Bent Creek on rehabilitating and regenerating degraded hardwood stands. Workers divided Bent Creek into dozens of research "compartments" with boundary markers and plans for managing and studying each. Scientists tested several types of management practices and maintained records of the costs and returns by compartment. Besides forest management and timber production, research began on erosion control, insects (southern pine beetle), diseases such as chestnut blight, and a regional fire warning system.

Highly degraded stands were the focus of Forest Service researcher **Jesse Buell**, who in 1930 performed one of the first clearcuts in the Southern Appalachians solely for research purposes. Buell designed the study to better understand the regeneration of "high-graded" sites where the larger, commercially valuable trees were removed first. The 6-acre site, known as the Buell Plot, is the oldest area at Bent Creek for which detailed data on hardwood regeneration and stand development are available.

Like scientists at other Forest Service stations across the country, Bent Creek researchers sought methods for preventing and eliminating forest fires. Bent Creek scientists developed a fire danger measurement rating system that, by the late 1940s, was used at 420 stations in 24 Eastern and Southern States. Bent Creek also received recognition for developing a fire visibility meter that has been used nationwide.

Protecting waterways was also an early concern at Bent Creek. In 1948, forester-in-charge **James F. Renshaw** wrote about the Nation's first extensive experiments in low-cost roadbank stabilization conducted at the experimental forest. "The findings were widely adopted for use on cut and fill banks by highway and railway engineers throughout the South," wrote Renshaw. Bent Creek researchers shared the results of these and other management studies with foresters, scientists, and private landowners through what today is referred to as technology transfer.

As the country mobilized for World War II, research slowed at Bent Creek and staffers conducted field studies on a custodial basis.

While Bent Creek researchers of the mid-20th century clearly recognized all the benefits that forests offered, timber management practices were a primary concern at the experimental forest after the war. Research sites of 100 acres or more were developed to study hardwood stand management. Researchers compared clearcuts to selection cuts, analyzed short versus long rotations, and studied levels of growing stock and farm woodland management.

The '60s Bring a Change in Perspective

Around 1960, under the leadership of **Charles McGee** and later **Don Beck**, research at Bent Creek expanded to build a more ecological approach to forest systems. Rising concerns about the environment in general meant that social acceptance of timber management methods, whether even-aged, two-aged, or uneven-aged (group selection), would become more important. Research on growth and yield included effects of thinning on understory plants and wildlife food sources.

Loftis cites a study by Bent Creek researcher **Lino Della-Bianco** that centered on precommercial thinning as a way to produce herbaceous browse for animals by allowing more light to reach the ground. "In the 1960s, a dual focus on timber production and forest composition and structure for wildlife emerged," says Loftis. "Della-Bianco also studied production of wild grape, another important wildlife food."

While Bent Creek scientists studied some artificial regeneration, research on natural regeneration methods dominated the program. Research on smaller plots replaced tests on large-scale sites because larger areas did not provide the detail required to understand site-specific ecology. Regenerating red oak on high-quality sites, growth and yield of yellow-poplar stands, and other long-term studies began.

By the 1960s, it was clear to researchers that yellow-poplar would almost always outgrow oak on good-quality sites. The challenges of regenerating oaks on good or excellent sites became the focus of most of the regeneration research at Bent Creek.

Mentors Beck and McGee introduced Loftis to the oak regeneration problem when Loftis joined Bent Creek as a graduate student in 1972 and, later, as a full-time employee in 1976. In the 1980s, Loftis studied the effectiveness of shelterwood cuts in regenerating oaks. He subsequently developed REGEN, a hardwood regeneration prediction model for the Southern Appalachians.

Early in the 1980s, **Henry McNab**, a research forester from the **Hitchiti Experimental Forest** in Georgia, joined Bent Creek. Site classification has been the heart of McNab's research since then. "A forested area isn't just the species of trees or other vegetation, but also the factors that influence what grows there—the soil, amount of sunlight, moisture, temperature. It's site classification but with an ecological twist," says McNab.

The 1990s and Beyond

The historical significance of Bent Creek was officially recognized in April 1993 when its facilities were listed in the National Register of Historic Places. Three years earlier, Loftis assumed the role of project leader of the SRS research unit housed on the experimental forest, establishing ecosystem management as the foundation for silvicultural research on upland hardwoods. At Bent Creek, scientists resurrected artificial regeneration research, particularly with respect to its role in restoration of oak and chestnut communities. They studied the effects of prescribed fire, exotic plants, and diseases on upland hardwood ecosystems.

Research ecologist **Katie Greenberg** joined the staff in 1995, bringing her expertise in wildlife research to Bent Creek. She has analyzed the effects of natural

(continued on page 6)

Margaret Stoughton Abell

Margaret Stoughton graduated from Iowa State College, Ames, IA, in 1930 with a bachelor's degree in forestry. In June 1930, she joined the staff of the **Appalachian Forest Experiment Station** in Asheville, NC, becoming the first woman forester in the Forest Service. Her name changed when she married **Charles A. Abell**, also a Station forester.

Stoughton Abell worked on nearly every project conducted at the Station early on, including experiments at the **Bent Creek Experimental Forest**. Stoughton Abell was also a skilled photographer as evidenced by the many photographs in Bent Creek's archives that bear her credit line.

In 1933, Stoughton Abell published an article titled "A Glimpse of the Appalachian Forest Experiment Station" in *The Ames Forester*, a publication of her Midwest alma mater. Included in the editor's note is the following: "Can a woman fill the position of a man in the field of forestry? Her field is no doubt limited in this role, but in research work Margaret Abell has proven beyond all doubt to her associates that she is capable."

In the article, Stoughton Abell tells the reader what he or she might encounter during a tour of the Station and of the research conducted at Bent Creek. Traveling along the Hardtimes Road (appropriately named as it was constructed during the Great Depression), the author points out a weather station, chestnut plots, and fire research plots along the way. She also discusses some early wildlife studies, "peculiar looking areas" used in watershed research, and entomological work performed at Bent Creek.

Stoughton Abell left the Forest Service in 1937, but not before leaving an indelible mark. Her entrance into the male-dominated field of forestry made her a pioneer, paving the way for future female foresters and scientists in the Agency. *—SW*

Margaret Stoughton Abell (Forest Service photo by Charles Abell)

Benk Creek

(continued from page 5)

disturbances such as Hurricane Opal, prescribed fire, two-aged harvests, and other silvicultural treatments on wildlife populations. Greenberg, who became project leader for the Bent Creek unit in 2007, also studies the production of mast and fleshy fruit as food sources for wildlife. Today, a "realigned" **SRS Upland Hardwood Ecology and Management Research** unit that includes Bent Creek and subteams in Arkansas, South Carolina, and Tennessee, has positioned itself to expand Bent Creek research on upland hardwood ecosystems to the regional level.

"Our unit is working with the North Carolina Wildlife Resources Commission, the Stevenson Land Company, and other partners to start a new regional study of oak ecosystem sustainability that is an extension and expansion of Loftis' work," says Greenberg. The study examines the impact of three silvicultural treatments on hardwood (primarily oak) regeneration, plant diversity, wildlife habitat quality, and wildlife populations on three sites chosen as representative of the upland hardwood ecosystems that stretch from Virginia through Arkansas. **Tara Keyser**, **Callie Schweitzer**, **Stacy Clark**, **Marty Spetich**, **Kay Franzreb**, **Susan Loeb**, and **Dan Dey** (Northern Research Station) are among those involved in the regional project.

As part of another project, Clark is leading a team of researchers who are trying to determine the best approach to restoring American chestnut in eastern hardwood forests. Clark is using experimental material from The American Chestnut Foundation to examine seedling response to a variety of forest conditions, including clearcuts, shelterwood harvests, and thinnings. This spring, the team established the first experimental plantings of blight-resistant trees in national forest locations in the Southern Region to determine how well the seedlings will compete in real-world forest conditions.

For more than 80 years, Bent Creek researchers have shared their knowledge of forestry with fellow scientists, foresters, landowners, and many others. In this photo, David Loftis leads a group of visitors on a tour of Bent Creek. (Forest Service photo)

Bent Creek's Contributions

Research from Bent Creek has contributed to the health and sustainability of Southern Appalachian forests. It's clear that one of Bent Creek's biggest contributions has been in the area of regeneration and management of Southern Appalachian hardwoods. Additionally, Bent Creek researchers have led the way in ecological classification and in research on hard and soft mast production for wildlife managers. However, it's possible that Bent Creek's most significant legacy could be its long-term datasets, established largely to document growth and yield and regeneration. These volumes of information, used by scientists of yesterday and today, could be key in understanding climate change and other environmental crises facing the United States in the future.

Collaborators:

University of Georgia, Duke University, Virginia Polytechnic Institute and State University, University of Tennessee, Clemson University, North Carolina State University, University of Kentucky, University of North Carolina (Chapel Hill and Asheville campuses), The American Chestnut Foundation, Southeastern State forest and wildlife agencies, and a vast network of forestry consultants and industrial foresters

For more information:

Bent Creek Experimental Forest: www.srs.fs.usda.gov/bentcreek/

Upland Hardwood Ecology and Management: www.srs.fs.usda.gov/uhem/

Compass, Issue 9, "The Mighty Oak: In Upland Hardwood Forests in the South" at www.srs.fs.usda.gov/compass/issue9/.

Recommended reading:

MacQueen, K. 2007. **Altered light: regenerating oak in upland hardwood forests.** Compass. 9: 3–5.

McGee, Charles E. 1972. **From a defective hardwood stand to multiple use opportunity.** Journal of Forestry. 700–704.

Nesbitt, William A. 1941. **History of early settlement and land use on the Bent Creek Experimental Forest, Buncombe County, N.C.** Asheville, NC: U.S. Department of Agriculture, Forest Service, Appalachian Forest Experiment Station. 47 p.

U.S. Department of Agriculture, Forest Service. 1995. **Bent Creek Research and Demonstration Forest: scientific forestry for informed choices.** Washington, DC. [Number of pages unknown].

1920s accommodations for Bent Creek researchers were somewhat primitive compared with today's laboratories. (Forest Service photo)

The Bent Creek landscape in the 1920s, around the time the experimental forest was established. (Forest Service photo)

Tracking Recreation at Bent Creek

by Claire Payne

Bent Creek provides a high profile example of the Forest Service's multiple use mandate. Located on the **Pisgah National Forest**, Bent Creek lies along the Blue Ridge Parkway, just minutes from Asheville, NC. The experimental forest is known internationally for long-term research on hardwood management, ecology, and regeneration.

Bent Creek also serves as a magnet for outdoor enthusiasts. Hikers, runners, hunters, and horseback riders visit in large numbers, but mountain bikers dominate. As Asheville's popularity and population have grown, recreation demand on the experimental forest has accelerated. Urbanization, the promotion of Asheville as a tourist destination, and even its location adjacent to the North Carolina Arboretum contribute to the large number of people who visit the experimental forest daily.

National and international groups tour Bent Creek to learn about shelterwood regeneration, hard mast studies, and disturbance events in the Southern Appalachians. The forest provides critical areas for established and new research plots to study wildlife, stand management, and forest health issues. Meanwhile, outdoor magazines feature Bent Creek as the premier mountain biking site in the Eastern United States. Bike riders are attracted by the large number of trails and mountainous terrain—even by the type of soil on the site. According to one mountain biker, the loose mountain soils add some cushion when he falls, lessening injuries. His only problem with Bent Creek is that it's too crowded on weekends.

Mike Bowker, research social scientist with the **SRS Integrating Human and Natural Systems in Urban and Urbanizing Environments** unit, is examining visitation, preferences, and economic values from recreation at Bent Creek. Bowker, as part of a team with SRS biometrician **Stan Zarnoch**, pioneering research scientist **Ken Cordell**, recreation planner **Carter Betz**, and University of Georgia cooperator **John Bergstrom**, designed a 2-year study that was implemented from June 2005 through June 2007. Bent Creek forestry technician **Julia Murphy** coordinated the survey, which resulted in 4,171 onsite contacts and 1,106 phone interviews.

Bent Creek, like a number of other Forest Service experimental forests, has witnessed a huge growth in recreation demand over the past 2 decades. "Cross-boundary mountain biking on unsanctioned trails, growing use loads from hikers and bikers, and conflicting interests from a number of organizations makes this study to establish a baseline of research on use and who the users are extremely important not only to Bent Creek but also to experimental forests nationwide," Bowker says.

Interviewers collected a stratified random sample of site days following the Forest Service National Visitor Use Monitoring (NVUM) protocol. First the annual site days were grouped

As Asheville's popularity has grown, recreation demand on the Bent Creek Experimental Forest has increased. (Photo courtesy Timm Muth)

according to season (spring, summer, fall, winter). Within each season, days were grouped by two levels of use—high and low. Weekend days are typically high, while weekdays are typically low. Hours of the day were also segmented according to two use levels. Key information from the NVUM interview process relates to visitor residence origins and demographics, recreation preferences and satisfactions, as well as knowledge and attitudes about the purpose of the experimental forest at Bent Creek, and the role and management objectives of experimental forests in general.

Data from the study will be used to test hypotheses about recreation visitor knowledge, attitudes, and preferences at Bent Creek, and to develop economic models estimating the value of recreational access to the experimental forest and the economic impact of this recreation on the Asheville, NC, economy. This research will serve as a model for studies on other experimental forests.

The research team is analyzing data and anticipates releasing results in 2009. "The study estimates total recreation visitation over a 2-year period," says Bowker, who is based in Athens, GA. "There has never been a study of this magnitude for this extended period of time."

For more information:

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The Sylamore
The role of fire in the Interior Highlands

Established in 1934, the **Sylamore Experimental Forest** (Sylamore) is located in the **Ozark-St. Francis National Forest** in a remote area about 100 miles north of Little Rock, AR. The oldest experimental forest in Arkansas, the Sylamore is also, at 4,180 acres, the largest in Arkansas. The size and remoteness of the site make it an ideal location for future research on woody biomass for biofuels, climate change monitoring, wildlife, and hydrology.

Oak-hickory stands interspersed with pines make up the experimental forest. Shortleaf pines are prevalent on south-facing slopes.

Early research at the Sylamore focused mainly on silviculture with numerous studies that developed and tested practices for managing upland hardwoods. Researchers also performed hydrologic research on local streams and evaluated the effects of timber harvesting on wildlife habitat.

Centuries ago, American Indians in the area frequently used low-intensity fires to clear the land and generate forage. But the frequency of fire in these parts declined along with the number of American Indians after European settlement. **Martin Spetich**, SRS research forester and manager of the Sylamore, is among the scientists trying to understand the historical role fire played in these forests.

Spetich oversees two keystone studies—one examines the patterns of establishment and development of oak-dominated stands, while the other is a thorough forest-wide inventory. As part of this last effort, researchers used the original 1934 plots to reinventory nearly 40 percent of the experimental forest in 2002.

The Sylamore is managed cooperatively with the Sylamore Ranger District of the Ozark-St. Francis National Forest, and is part of an Arkansas Fish and Game Wildlife Management area. *—SW*

The oldest and largest experimental forest in Arkansas, the Sylamore is made up of oak-hickory stands interspersed with pine. (Photo by Bill Lea, Forest Service)

The Koen
Upland hardwood field research in Arkansas

Established in 1951, the **Henry R. Koen Experimental Forest** (Koen) is located in northern Arkansas, and consists mainly of oak-hickory upland hardwood forest and oak-pine stands. Named for **Henry R. Koen**, forest supervisor of the **Ozark National Forest** in the first half of the 20th century, the experimental forest was established to develop scientific principles for forest management. At 720 acres, the Koen is the smallest of the 19 experimental forests managed by SRS.

Forest Service facilities include an office, garage, and workshop. The Koen also features a handicapped accessible nature trail established in collaboration with several local civic organizations. Visitors from across the United States and around the world use the trail and picnic area.

Through 1979, research at the Koen focused on upland hardwood forests with a staff of 4 scientists and a team of 12 technicians. Researchers conducted numerous studies from the early 1940s to the late 1970s which included the effect of stand structure on white oak stands, forest inventory sampling design, improvement harvesting, and small woodland management. Two long-term datasets resulted from research at the Koen: a study of redcedar that began in the 1940s and ran through the early 1960s, and a watershed study that ended in the late 1970s.

Today, the Koen serves as the fieldwork base for SRS upland hardwood research across Arkansas. SRS research forester **Martin Spetich** manages the Koen, where he and two permanent field technicians are implementing 17 major studies. The integrated research program addresses upland hardwood forest dynamics and the development of both short- and long-term studies at three scales: individual tree, stand, and region. These studies address forest species restoration, quantitative silviculture, development of forest management methods, forest ecology, disturbance ecology, landscape ecology, climate change, forest biomass, and diversity of Arkansas upland hardwood forests.

The role of fire in upland hardwood forests is an important element of the research. One of two keystone studies analyzes the effect of fire on species dynamics in the Ozark-Ouachita Highlands and examines burned and unburned areas in combination with a number of other treatments. The other keystone study is being done at the landscape scale. Spetich and University of Missouri collaborator **Hong He** are adjusting LANDIS (a landscape disturbance model) to predict future impacts of current management across the Boston Mountains in Arkansas. *—SW*

Collaborators:

Ozark-St. Francis National Forest, Job Training Partnership, U.S. Army Reserve, and Jasper Chamber of Commerce

Though the smallest of the SRS experimental forests, the Koen serves as field base for 17 major upland hardwood studies. (Photo by Bill Lea, Forest Service)

Blue Valley
The ecology of eastern white pine

The **Blue Valley Experimental Forest** (Blue Valley) lies in southwest North Carolina in the **Nantahala National Forest**. It's located in Macon County, near the point where North Carolina meets Georgia and South Carolina. Established in 1964, the 1,300-acre experimental forest is the smallest of the three experimental forests in North Carolina and the second smallest of the 19 managed by SRS.

Blue Valley's landscape is dominated by eastern white pine, but includes oak-hickory stands. Experts believe extensive grazing and logging around the turn of the 20th century contributed to the abundance of eastern white pine. The infertile soil is typical of the southern highlands. Buckberry is the most prevalent of the ericaceous (acid loving) shrubs that dominate the forest understory.

Research studies at Blue Valley started in 1995, and include experiments on management practices such as single-tree selection cutting in white pine/hardwoods, shelterwood and underburning in white pine/hardwoods, and bark beetle populations. Blue Valley also provides opportunities to study the fundamentals of white pine ecology (including seed production and dispersal), ericaceous shrubs, and low-fertility sites.

Henry McNab, research forester with the SRS upland hardwoods unit, manages Blue Valley. *—SW*

Research studies at Blue Valley began in 1995, and include management experiments on eastern white pine-hardwood stands. (Photo by Joseph O'Brien, Forest Service, www.Bugwood.org)

Located in western North Carolina, the Coweeta Hydrologic Laboratory is made up of two adjacent, bowl-shaped basins that contain 300 separate watersheds and over 45 miles of stream. (Forest Service photo)

Water for the South

Coweeta

Long-term data for today's problems

by Gary Kuhlmann

His Forest Service predecessors certainly knew what they were doing when they established the **Coweeta Experimental Forest** back in 1934, according to **Wayne Swank**, former Coweeta project leader.

Southern Appalachian forests were just beginning to grow back after the intense timber harvesting that began in the 1900s and lasted well into the 1920s, notes Swank (currently an emeritus scientist at Coweeta), and while the Coweeta Basin looked like the perfect place to study the effects of logging on streams, researchers had little understanding of regional streamflow and climate patterns. When Forest Service ecologist **Charles Hursch** came up with the idea of installing instrumented weirs in the streams of the Coweeta forest to monitor climate and hydrology, the practice became a model for experimental forests throughout the Nation. The Forest Service went on to set up 24 sites with instrumented stream weirs around the country.

In only a few years, workers with President Franklin Roosevelt's Civilian Conservation Corps built Coweeta's original laboratory buildings, climatic stations, roads, and stream measurement devices. Much of their work still stands, including the stream weirs that have given SRS scientists decades of baseline data invaluable for charting the changes now taking place in the forests of the South.

Data from stream weirs gives scientists windows on a hidden world where water is an integral and integrating factor in many natural processes. The gauged weirs are equipped with instruments that measure the physical and chemical characteristics of the water that flows through them, enabling researchers to measure the interactions among factors such as nutrient cycling, acidity, vegetation changes, and natural disturbance.

The Coweeta Basin is richly endowed for forest hydrology research. Located in the Nantahala Mountain Range in western North Carolina, the 5,400-acre laboratory is made up of two adjacent, bowl-shaped basins covered with forest that contain several well-defined watersheds and more than 45 miles of stream. Ecologist Hursch picked Coweeta because of the terrain, and because the area has some of the highest annual rainfall in Eastern North America. All that rain penetrates the litter of a mixed-hardwood forest to be immediately absorbed by deep permeable soils. Under those soils there's solid bedrock that forms a temporary water trap, making it easier for hydrologists to account for most of the rainfall that enters the basin.

For more than 7 decades, across 16 watersheds, hydrologists, technicians, and others at Coweeta (renamed the **Coweeta Hydrologic Laboratory** in 1948) have recorded data from rain gauges and gauges installed in streams, calculating water budgets from input and outflow, studying the hydrologic cycle of the mountains. Though some gauges are automated now, Coweeta staff once literally collected the data by hand, riding horses on a daily circuit that took them up and down the wooded basins. The records they and those following them kept constitute the longest and most accurate information in existence on rainfall and streamflow from small forested watersheds. These long-term records form the backbone of a research program that has targeted a wide range of impacts on water resources, from roads to ozone damage and the loss of foundation forest species.

The Pressure's On

Since these data make up a continuous history, they become more valuable each year. Periods of drought in the past couple of decades have pushed concerns about water to the forefront, according to **Jim Vose**, ecologist and current project leader for Coweeta.

"With population across the Southeastern United States expected to grow by as much as 30 percent in the next 30 years, municipalities will rely more and more on forested watersheds to offset or mitigate the impacts of growth, while land use change

(continued on page 14)

Coweeta

(continued from page 13)

and climate variability will make it increasingly difficult to keep up with the demand," Vose says.

Coweeta research has shown that even a mile of forest makes a difference in water quality. Much of what is known about the importance of watersheds in providing clean water for human consumption and wildlife habitat comes from nearly a century of research at Coweeta on water-quality issues.

Some of Coweeta's earliest experiments demonstrated the harmful effects of exploitive logging and improper road construction, farming on steep mountain slopes, and woodland grazing—all common practices throughout the Appalachians at that time. Hursch designed four paired watershed experiments in the 1940s that showed that it's not cutting trees per se that causes erosion and sediment runoff, but the disturbance from roads and traditional timber practices such as building skid trails directly up steep slopes and roads right next to, sometimes in, streams.

Besides changing road-building practices, the paired watershed experiments gave scientists a basic understanding of the hydrology of the Southern Appalachian region—and how land management can be used to affect both water quality and quantity. Coweeta research went on to show that in addition to roads and road construction, the forest practices with the most potential for causing erosion and stream sedimentation are tractor skidding (as opposed to cable or aerial removal) and intensive site preparation. In 1945, **Marvin Hoover**, for example, found that careless skidding reduces the benefits of forest cover for watershed protection by creating channels that concentrate runoff from road surfaces. In 1977, **James Douglas** and **Lloyd Swift** published on soil and nutrient losses caused by roads, logging, mechanical site preparation, and prescribed burning.

Coweeta's early emphasis on how land management practices affect the hydrologic cycle evolved into a broader interdisciplinary effort that began looking at a wide array of complex ecological interactions. When former project leader Swank arrived at Coweeta in 1968, he began monitoring stream chemistry to measure the effects of disturbance and long-term trends. His work and that of Swift, **John Hewlett**, and others established the use of stream chemistry criteria as signatures of an ecosystem response to disturbance in a watershed, allowing scientists to detect emerging threats that might otherwise have escaped notice.

Today, Coweeta soil research scientist **Jennifer Knoepp** and ecologist **Katherine Elliot** study the effects on stream chemistry of disturbances such as prescribed burning or the loss of foundation species such as American chestnut and Eastern hemlock. Ecologist **Barry Clinton** is looking at the effects of tree canopy loss, while Vose is investigating the effects of ozone damage. Meanwhile, ecologist **Chelcey Ford** is linking together tree physiology and stream chemistry data to look at the effects of tree species diversity on water quantity and quality.

Coweeta scientists take an interdisciplinary approach to understanding how watershed systems respond to natural and human disturbances. The more scientists understand about the interconnections between climate, vegetation, soils, and water the better they can be at developing management practices to deal with the consequences of disturbance, according to Vose. Because this approach requires integrating many scientific disciplines, Coweeta's staff roster is made up of ecologists, hydrologists, soil researchers, chemists, and many others, including collaborators both regional and worldwide.

Swank, shortly after coming onboard at Coweeta, started a unique long-term collaboration with the University of Georgia (UGA) that led to the selection, in 1980, of Coweeta as one of the first sites in the **National Science Foundation Long-Term Ecological Research** (LTER) network. The centerpiece of continuing cooperative efforts between Coweeta and UGA, the program includes other major university cooperators. The LTER program addresses region-wide issues, with Coweeta studies focused on Southern Appalachian forests, as well as on predictive models for how land changes and population pressures will affect water quality and quantity in the South.

"It's time to shift our focus to larger scales and to cumulative effects over longer periods of time," says Vose. "With advances in computing technology and improved understanding of physical and biological processes, we are positioned to develop more complex models at larger scales."

Collaborators:

Clemson University, University of Georgia, University of Virginia, Furman University, University of North Carolina-Chapel Hill and Asheville, Duke University, Virginia Polytechnic Institute and State University, North Carolina State University, Northern Arizona University, Oregon State University, University of Wisconsin, University of Minnesota, University of Tennessee, University of Maine, Mars Hill College, Desert Research Institute, U.S. Environmental Protection Agency, U.S. Air Force, U.S. Navy, National Aeronautics and Space Administration, and other units of the Forest Service, National Forest System

For more information:

Coweeta Hydrologic Laboratory: www.srs.fs.usda.gov/coweeta/

Recommended reading:

Clinton, B.D.; Vose, J.M. 2006. **Variation in streamwater quality in an urban headwater stream in the Southern Appalachians.** Water, Air, and Soil Pollution. 169: 331–353.

Elliott, K.J.; Swank, W.T. 2008. **Long-term changes in forest composition and diversity following early logging (1919–1923) and the decline of American chestnut (*Castanea dentate*).** Plant Ecology. 197: 155–172.

Elliott, K.J.; Vose, J.M. 2005. **Initial effects of prescribed fire on quality of soil solution and streamwater in the Southern Appalachian Mountains.** Southern Journal of Applied Forestry. 29(1): 5–15.

Swank, W.T.; Crossley, D.A., Jr. 1988. **Forest hydrology and ecology at Coweeta.** New York: Springer-Verlag. 469 p.

The weirs used to collect long-term hydrologic data were originally built by Civilian Conservation Corps workers in the 1930s. (Forest Service photo)

The Santee
Heading off threats to water supply and quality

by Gary Kuhlmann

Hydrologic research at the **Santee Experimental Forest** (Santee) also took root in environmental concerns, when, in 1934, the Forest Service allocated 6,100 acres of the **Francis Marion National Forest** (Francis Marion) near Charleston, SC, for the research site.

By the 1930s, much of the site had been heavily managed and abused for centuries. The upland had been cleared to raise livestock and produce naval stores (tar, pitch, turpentine, and other products from pine), while rice and indigo were cultivated in the bottomlands. Between 1897 and 1929, the area was heavily logged. Early research on the Santee focused on thinning and fire management in loblolly pine stands.

In the 1960s, in response to new concerns about the impacts of a burgeoning timber industry, researchers **Cortland Young, Jr.** and **Ralph Klaiwitter** set up gauged weirs in the Santee's streams and weather stations on the watersheds draining these streams to study the effects of forest management activities on the soils and waters of the Coastal Plain. Researchers and technicians have recorded data in the Santee—with some significant breaks—since 1964.

The Santee contains four gauged watersheds of different sizes. Young and Klaiwitter began their first long-term hydrologic observations in 1964, using the four watersheds to study soil moisture dynamics and runoff processes, as well as the effects of different types of land management practices such as understory eradication (through prescribed burning), clearcutting, thinnings, and constructing drainage and impoundments.

Though not much was published from data measured between1964 to 1982 on these experimental watersheds, the work of Young and Klaiwitter was fundamental in documenting a hydrology altogether different from mountain watersheds.

"In the mountains, water moves fast down steep slopes, but in coastal areas, water moves in a slow, diffuse way," says **Carl Trettin**, team leader for the research unit at Santee. "This means that Coastal Plain rivers carry much less sediment, and the riparian zone is much wider, so much more sediment is captured before it can enter the stream. This also means greater potential for mitigating nutrients such as nitrogen because the water is moving slow enough for the denitrifying bacteria to do their job."

These differences in waterflow, water balance, and pollutant cycling processes between mountain and coastal landscapes underscore the importance of the long-term data collected from the Santee weirs and rain gauges, especially now, as changing land uses put new pressure on water sources in the Coastal Plain.

After 1982, there were no Forest Service hydrologists around to analyze data from the weirs and rain gauges

View of Huger Recreational Area across from the entrance road to the Santee Experimental Forest headquarters. (Forest Service photo)

on the Santee. Fortunately, technicians on the site steadily kept records over the years (except from 1982 until after Hurricane Hugo in 1989) from both weirs and weather stations, storing them in whatever format was available at the time—tape, floppy discs, and often on paper.

The Charleston unit finally got another research hydrologist, **Devendra Amatya**, in 2002. With urban development fast encroaching on the Francis Marion, pushing water-quality issues to the forefront, Amatya began bringing together a wide range of cooperators interested in using science to ensure water quality and quantity in the Charleston area. In 2004, he started a research initiative focused on the Turkey Creek watershed in the Francis Marion with partners from colleges and universities, private industries, and State and Federal agencies joining SRS scientists in studies of the urbanizing landscape in relation to water quality.

One of the gauged weirs set up more than 40 years ago on the Turkey Creek watershed has been revived to provide the long-term baseline data that will help SRS scientists and regional planners look at the effects of land management and climate on the poorly drained watersheds of the Coastal Plain. The first task of the Turkey Creek initiative was to resume hydrologic monitoring of streamflow and climatic data, followed by water-quality sampling and analysis of historic data. Researchers need to understand more about the cumulative effects of forest management activities such as prescribed fire on wetlands, Amatya says. Turkey Creek, sitting on the edge of the national forest, also presents a unique opportunity as a baseline reference to look at the effects of urbanization on water quantity and quality as development creeps closer and more nearby residents use public lands for recreation.

No matter what happens, the real challenge, Amatya says, is to not let new threats—from population growth to climate change—catch scientists and leaders off guard.

To head off that surprise, Amatya wants to take advantage of technological advances and broader coalitions to address issues that threaten forest health over ever-increasing boundaries. Trettin and Amatya are working with **JimVose** from Coweeta as well as with **Steve McNulty** and **Ge Sun**, both with the **SRS Southern Global Change Program**, to understand more fully what happens to water as it moves from mountain headwaters through the Piedmont regions and into the Coastal Plain. The team is incorporating long-term data and historical hydrologic studies from Coweeta and Santee into computer models designed to help local officials across the South understand how population growth and climate change will affect water availability in the coming years.

Research on the Santee was fundamental in documenting a hydrology altogether different from mountain watersheds.

"I can't stress enough the value of data from sustained long-term Forest Service research," says Trettin. "Now we're poised to move forward with partners, using our long-term hydrologic data to measure new impacts on water and on the Coastal Plain—and at the same time, develop and test models that planners and managers need to make decisions."

Collaborators:

The College of Charleston, Clemson University, University of South Carolina, Virginia Polytechnic Institute and State University; scientists and staff from MeadWestvaco, International Paper, Oak Ridge National Laboratory, and the Native Plant Society; and staff from the Francis Marion National Forest

For more information:

Santee Experimental Forest: www.srs.fs.usda.gov/charleston/santee/index.html

Compass, Issue 5, "From Mountain Headwaters to the Sea: Forests Clean Our Water" at www.srs.fs.usda.gov/compass/issue5/

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Amatya, D.M.; Trettin, C.C. 2007. **An eco-hydrological project on Turkey Creek watershed, South Carolina, U.S.A.** In: Miere, P., [and others], eds. Integrated water management: practical experiences and case studies. NATO Science Series IV: Earth and Environmental Sciences. Netherlands: Springer: 115–126.

Alum Creek

Hydrologic studies in the Interior Highlands renewed

The 4,660-acre **Alum Creek Experimental Forest** (Alum Creek) was established in the late 1950s in the upper headwaters of the Lake Winona Basin near Jessieville, AR. Managed by the **SRS Southern Pine Ecology and Management** unit, Alum Creek is affiliated administratively with the **Ouachita National Forest**.

From 1960 until the mid–1980s, Alum Creek was primarily used to study the effects of different silviculture treatments on forest hydrology. During this period, 10 small watersheds were instrumented to monitor streamflow and water quality; two weather stations were established to measure precipitation, air temperature, and other meteorological variables. Data series ranging from 20 to 40 years have been collected from the gauging stations on the 10 small watersheds; three of the stations are still used to record long-term baseline data.

Past studies using these data have established the effects of silviculture treatments on streamflow amounts and water quality within the Ouachita Mountains. These studies parallel

H-flume at the mouth of Watershed #4 in Alum Creek Experimental Forest. (Forest Service photo)

those undertaken at other gauged sites within the Interior Highlands, as well as those at Coweeta and the Santee.

Dan Marion, though research hydrologist with the **SRS Center for Bottomland Hardwoods**, is actually stationed in Hot Springs, AR, where the primary focus of his research is on the effects of forest management on the watershed processes of the upland forests of the Interior Highlands. Marion is using the gauged systems on Alum Creek to quantify the movement of water, sediment, and nutrients—and as the basis for developing models for other areas of the region.

"In contrast to other regions, there's been no consistent nexus of hydrologic research in the Interior Highlands," says Marion. "Since the 1930s, the work has shifted among several locations, including Alum Creek and the Koen." Meanwhile, management goals for forests have shifted from improving timber values to restoring ecosystems and maintaining their integrity. "These newer goals affect our thinking about water resources and research needs," says Marion. "At the same time, societal concerns about the effects of forest practices have shifted from concerns about floods, to water quality, to downstream or cumulative effects on water resources."

Marion notes the importance of Alum Creek as a field site for research on upland forest hydrology in Arkansas. "Much of what we know about how to manage Ouachita Mountains' shortleaf pine and pine-hardwoods forests in ways that minimize adverse effects on soils and water comes from Alum Creek," says Marion.

In the mid–1990s, the scale of research changed as Alum Creek became part of a large ecosystem management study across the upper Lake Winona Basin that encompasses the experimental forest. This new research program investigates the landscape-level effects of different kinds of forest management on vegetation, soils, water, and wildlife. To support this research, three new gauging stations were added to the existing hydrometeorological network at Alum Creek. Similar stations were established in two adjacent basins, as well as in a basin managed using industrial forestry practices. Each basin serves as an example of different silvicultural treatments applied to large (greater than 1,000-acre) areas.

"In addition to evaluating the effects of different treatments on forest streams, this work will provide excellent reference data for streamflow within managed forest landscapes of the Ouachita Mountains," says Marion. "It may also prove useful in landscape-based wildlife studies, where riparian habitat use by migratory birds and forest bats, for example, may be greatly affected by streamflow occurrence and persistence." —ZK

Collaborators:

Ouachita National Forest, Weyerhaeuser Company, University of Arkansas and University of Arkansas-Monticello, Oklahoma State University, Mississippi State University, University of Oklahoma, Texas A&M University, and University of Kentucky

For more information:

Dan Marion at 501–623–1180, x104 or dmarion@fs.fed.us

Oak-hickory forest near the Ouachita Mountains in Arkansas. (Photo by Bill Lea, Forest Service)

The Delta

From bottomland hardwood restoration to food for the "lord god" bird

This 2,600-acre bottomland forest is owned and managed by Mississippi State University (MSU). The **SRS Center for Bottomland Hardwoods Research** conducts research there under a long-term cooperative agreement. Located in Washington County, the site was established in 1945 by the Forest Service as an experimental forest through a cooperative agreement with the State of Mississippi. Until the 1970s, the **Delta Experimental Forest** (Delta) was a working forest; timber receipts paid for a crew of technicians to establish and maintain research studies conducted by Center scientists.

Research during the first 30 years involved thinning studies, developing methods for growing quality southern hardwoods, evaluating results of efforts to improve eastern cottonwood clones, and studying the progression of heartrot diseases and the life cycles and impacts of insect borers. Later studies included determining the causes of oak decline and investigating red oak-sweetgum stand dynamics.

These studies provided much of what is now known about growing different tree species in the poorly drained but fertile soils deposited by the Mississippi River. In addition, several eastern cottonwood clones selected during the 1960s and 1970s by SRS geneticists and tested in the Delta are still used by forest industry throughout the South, by government agencies, and in many foreign countries around the world.

The 1970s brought changes in State priorities that resulted in a decline in both forest operations and new studies on the Delta. By the mid-1990s, heartrot had degraded many of the older trees on the site, and ice storms had damaged the crowns of most canopy trees. Most of the Delta forest was cut in the late 1990s to regenerate degraded forest stands. Oak seedlings were planted to supplement natural oak regeneration.

A Multifaceted Resource

In the last decade, the Delta has become home for a new round of experiments that combine the expertise of SRS scientists in the bottomland hardwoods unit on subjects ranging from wood-destroying insects and fungi to food for ivory-billed woodpeckers.

Silviculture study on Delta National Forest. (Forest Service photo)

Research entomologist **Nathan Schiff** and research plant pathologist **Dan Wilson** have joined forces to better understand the symbiotic interaction between woodwasps and wood decay fungi. Like other wood-boring insects, woodwasps are unable to break down cellulose themselves. The insects carry wood decay fungi in special glands; when they lay their eggs under tree bark, they also inject the fungi. When the larvae hatch, they feed off wood rotted by the fungi, boring further in until they emerge 1 to 3 years later. Schiff and Wilson conduct studies on the Delta to identify the fungus species used by woodwasps, measure damage to trees and wood, and explore novel ways to control the wasps and fungi. Woodwasps are of particular concern because their larvae are often transported in lumber to areas where they become nonnative invasive pests, wreaking havoc on native tree species.

The Delta also hosts a site for the study set up by Schiff and wildlife biologist **Paul Hamel** in 2006 to look at food availability for the ivory-billed woodpeckers rumored to still inhabit the Big Woods areas of Arkansas and Mississippi. Previous researchers had concluded that the disappearance of the "lord god" bird might be linked to declines in the insects the species preferred. Hamel started his investigations with a list of insects **James Tanner** had identified in the 1940s by looking at stomach contents and nest leavings of the few ivory-billed woodpeckers remaining. When Schiff looked at Hamel's list, he immediately noticed that all the insects on it were borers. These insects would not have been available to the birds by just stripping the bark; the woodpeckers may have relied on the periodic emergences of adults from injured trees for their meals.

Larvae of insects under study as possible food sources for the ivory-billed woodpecker. (U.S. Forest Service photo by Nathan Schiff)

Hamel and Schiff started a study that involves subjecting trees from species that had been identified as primary ivory-billed woodpecker forage trees to four different levels of wounding, allowing insects a growing season to lay eggs, then using isolation chambers to measure the numbers of emerging insects in relation to the level of wounding. The study, a unique ecological assessment of the types and numbers of insects infesting dead and dying trees, will also yield broader information about insect predation and tree condition useful to forest managers.

In the Future, Wood for Energy

A future project brings research at the Delta full circle, back to the question of how to most efficiently grow hardwoods on the more difficult soils of the region. In cooperation with MSU, SRS researchers are planning to establish a bioenergy plantation study on the experimental forest as early as 2009. Experimental plots will be set up to test the potential of fast-growing hardwood tree species that can survive the area's heavy clays—such as sycamore, black willow, and red maple—as alternative sources of energy. The study will be one of the first to test red maple as a possible bioenergy source. *—ZK*

To read more about SRS bottomland hardwoods science, see Issue 6 of *Compass* online at www.srs.fs.fed.us/compass/issue6/.

Collaborators:

Mississippi State University, Mississippi Forestry Commission, US Fish and Wildlife Service, Yale University, forestry consultants, and industrial foresters

The Tallahatchie

Tornadoes create new research opportunities

by Claire Payne

On February 5, 2008, one or more tornadoes roared through the **Tallahatchie Experimental Forest** (Tallahatchie) on the **Holly Springs National Forest** near Oxford, MS. The winds blew down, snapped, or damaged trees on about 75 percent of the 3,500-acre forest. The storm track included four of the seven experimental plots **Steve Brewer**, associate professor of biology at the University of Mississippi, had established in 2000 to measure how different seasons of prescribed fire affect regeneration of native and nonnative plant communities. He had already collected extensive data about herbaceous, understory, and overstory plant species.

The tornadoes created a gradient of damage ranging from hardly affected to nearly all trees either down or topped. Staff at the Holly Springs Ranger District wanted to salvage log the damaged trees. Brewer, with research biologist **Mel Warren** and research plant pathologist **Ted Leininger** from the **SRS Center for Bottomland Hardwoods Research** worked with the district to establish additional plots in the tornado-affected areas. They set up plots where logging would occur and comparison plots that would be allowed to regenerate naturally with no disturbance from salvage logging.

Because so much information had been collected prior to the storm, the stage was set to determine not only what was lost but also how the land would respond to different treatments. Because they were working on an experimental forest, researchers were able to change the storm damage from a problem into an opportunity. "Rarely has this been done, to compare storm-related damage to effects of storm-related damage plus salvage logging," Brewer says.

Usually when researchers study salvage-logged versus nonsalvage-logged areas, they focus on tree species, seedlings, and regeneration. For this study, Brewer, Warren, and Leininger are taking a broader view, examining the entire plant community, including those with nontimber values such as contributing to biodiversity and benefiting wildlife. In the salvage-logged plots, trees and even tree seedlings are doing well, but native plants don't seem to be recovering as well. According to Brewer, who cautions that it's too early to make a definitive statement, preliminary

Shoreline of the Little Tallahatchie River near Oxford, MS. (Photo by Jim Cleveland)

results show native plants adversely affected as invasive species move into the areas that were salvage logged. In the plots allowed to regenerate naturally without salvage logging, native flowering plants are emerging from the seed bank.

Brewer explains that these areas were historically open, with savannah species whose growth was suppressed by the closed canopy forest. The natural disturbance of the tornadoes has created more light, allowing herbaceous ground cover species to return. Though effects on wildlife are not within the parameters of Brewer's study, he reports that legumes—an important food source for quail and turkey—are growing very well.

The Tallahatchie was established in 1950 to study relationships between mixed pine and hardwood forests, flooding, and soil erosion. Three small pine-hardwood watersheds were established in 1959 about one-third mile east of the Tallahatchie and are informally considered part of the experimental forest. Primary research opportunities abound in hydrological studies of these small basins, where data has been collected for over 40 years.

One of the primary projects supported by work on the experimental forest and associated hydrological research was the **Yazoo-Little Tallahatchie Project**, a large Federal reforestation and soil stabilization effort which was conducted in northern Mississippi from 1949 to 1985. Research on the Tallahatchie has contributed significantly to improving forest management in several areas, providing information on the effects of timber harvest on runoff rates and sediment yields from basins with highly erodible soils, documenting the effects of cool season prescribed fire on plant and bird communities, and increasing recognition that hot season fire in the Upper Coastal Plain may be critical for effective and efficient improvement of forest condition, health, and diversity.

Collaborators:

University of Mississippi, Holly Springs Ranger District, National Forests in Mississippi

For more information:

Mel Warren at 662–234–2744, ext. 246 or mwarren01@fs.fed.us

Wild turkey eggs. Legumes—an important food source for turkeys—are growing back well in study plots in the Tallahatchie. (Forest Service photo by Ted Leininger, www.Bugwood.org)

Longleaf pine forests, which once dominated an estimated 92 million acres in the Southeastern United States, now occupy only 3 percent of their former range. (Forest Service photo by William Boyer, www.Bugwood.org)

The Return of Longleaf Pine

by Zoë Hoyle

Longleaf pine forests once dominated an estimated 92 million acres in the Southeastern United States. Since the 1770s, logging, naval stores production, conversion to other land uses, and fire suppression have effectively reduced longleaf pine forests and the unique ecosystems they harbor to a mere 3 percent of their former range. Today, there's growing interest in restoring not only longleaf pine, but the unique forest ecosystems the tree supports. In the past, research conducted on several experimental forests managed by SRS played a critical role in the revival of longleaf pine as a viable choice for timber. Today, longleaf pine stands are rarely established for timber production alone, but most often to restore the ecosystem within its native range and to provide habitat for the rare and endangered species—red-cockaded woodpecker, gopher tortoise, Louisiana pinesnake, and others—it uniquely shelters.

Full length story, "Crowning Glory," available online at www.srs.fs.fed.us/compass/summer2005/01crowningglory.htm

Early research on the Escambia focused on natural regeneration of longleaf pine stands. (Forest Service photo)

The Escambia

A living laboratory for longleaf pine regeneration

by Zoë Hoyle

When the **Escambia Experimental Forest** (Escambia) was formally established in 1947, there were about 6.2 million acres of second-growth longleaf pine trees remaining across the southern Coastal Plain. Many timber producers had already switched to faster growing loblolly and slash pines. Although others were still open to growing longleaf for timber, they just weren't sure they could make money when site preparation and planting costs were factored in. Enter **Tom Croker**, the Forest Service scientist who helped set up the experimental forest and managed research there until he retired in 1974.

The first research on the Escambia focused on longleaf pine management issues including natural regeneration, growth and yield, rotation lengths, thinning regimes, and economic costs and returns. From observing the remaining longleaf pine stands on the Escambia, Croker knew that with enough mature trees, natural regeneration alone could replenish timber stands, cutting out planting and site preparation costs. He showed that leaving a certain number of high-quality, well-spaced trees per acre provided enough seed trees for natural regeneration while retaining a sheltering overstory into the next rotation. Over time, this method became known as the shelterwood system, where older trees are removed as new stands develop. Essentially an even-aged method, (with cohorts of trees all the same age), over time the shelterwood method results in multi-aged, open stands with tall, straight trees.

From 1947 to 1975, Croker's Brewton project (named for town nearest to the experimental forest), was devoted almost entirely to developing the shelterwood system, which has proved highly successful for regenerating longleaf pine. Yet despite regeneration research, longleaf pine plantations were dwindling by the 1960s. "There were so many failures of longleaf plantations throughout

Scientists are using the long-term data from the Regional Longleaf Growth Study started on the Escambia to look at the impacts of increased levels of atmospheric carbon on longleaf pine growth. (Forest Service photo)

the South in the 1950s and 1960s that most foresters considered the practice too risky and switched to slash and loblolly pine," Croker wrote in his seminal study on longleaf pine. Landowners and managers needed more evidence that longleaf pine could be grown productively.

A New Generation of Champions

William (Bill) Boyer had never seen a longleaf pine before he started working on Escambia studies in 1955, but he soon became a champion of the tree, and continues (even though he officially retired in 1998) to study ways to improve longleaf pine regeneration and survival. In 1975, Boyer and Croker published the guidelines for longleaf pine natural regeneration still followed today.

In 1964, Boyer and fellow SRS researcher **Robert Farrar** started the **Regional Longleaf Growth Study** (RLGS) on the Escambia, installing additional study sites in Mississippi, Florida, Georgia, and North Carolina over the next 3 years. RLGS was started to build a database of growth-and-yield information for naturally regenerated, even-aged stands. Originally made up of 185 plots, the study was designed to cover a range of ages, stand densities, and site qualities. Every 10 years RLGS adds new plots in the youngest age class. Today the study consists of 305 plots; nearly half of these are located on the Escambia.

Over the decades, Boyer and Auburn University's **John Kush** have worked to keep this unique study going and to make sure data is recorded. All RLGS plots are remeasured every 5 years; in 2009, the 45-year remeasurement will be taken. The science-based knowledge of natural stands of longleaf pine generated by Boyer and Kush is unprecedented, their influence on the field continued through new generations of graduate students, researchers, and forest managers. The long-term datasets from the study have been invaluable. Researchers have shown, for example, that naturally regenerated longleaf pine trees catch up and surpass planted trees in 33 years. For a landowner with natural stands of longleaf pine, this means planting costs could be greatly reduced or eliminated.

In recent years, Kush and students have been using RLGS plots and databases to look at the impacts of increased levels of atmospheric carbon dioxide on longleaf pine growth. This new research came about because Boyer, while analyzing long-term data, noticed significant differences between second- and third-growth stands in the study. Now researchers are starting to explore whether the carbon storage capacity of longleaf pine could encourage incentives for planting the tree to mitigate climate change.

Rekindling the Flame

To remain healthy, longleaf pine forests need periodic fires to reduce midstory competition from hardwoods. In 1947, a large wildfire in the Escambia area prompted managers to burn another 26,000 acres of land in and around the newly established experimental forest. Observing the successful regeneration of longleaf pine seedlings on the burned areas led scientists and others to promote fire, long considered an enemy to U.S. forests, as necessary for establishing longleaf pine stands. Croker observed that most of the regeneration in his seed tree plots was due to fire rather than the presence of seed trees; the seed tree method was abandoned on the Escambia as prescribed burning became an accepted management tool.

Boyer began experiments with fire in the 1960s, and found that longleaf pine was surprisingly tolerant to low-intensity fire. Fire studies have now been in place since 1973, including studies on the long-term effects of season and frequency of prescribed fire, as well as effects on forest floor vegetation. **Dale Brockway**, SRS research ecologist, tests prescribed fire as one of a suite of tools managers can use to restore and manage longleaf pine forests. He's developed uneven-aged management methods for landowners who are interested in creating wildlife habitat, restoring understory plant diversity, aesthetics, and other values.

Although much is now known about even-aged management of longleaf pine stands, little is known about the long-term results of uneven-aged management, which promotes regular regeneration by creating the types of gaps that would normally occur from disturbances such as lightning, insects, fire, or wind. Since 2004, Brockway has been testing single-tree and group selection methods for regenerating longleaf pine. He and fellow researchers have developed and tested a new silvicultural technique that managers and field personnel can easily learn and cost-effectively apply to manage forests for a broader range of structures and values.

Today, a little over 80 percent of the Escambia is in upland longleaf pine stands, the rest in slash pine and hardwood bottoms. Since management began in the 1940s, about 1,200 acres have been naturally regenerated to longleaf pine. What makes the Escambia unique is that it now shows longleaf pine in all stages of development, from newly germinated seedlings to mature trees up to 160 years old.

(continued on page 28)

The Escambia

(continued from page 27)

"The combination of stand ages, sites, and conditions exists nowhere else," says Boyer, who started working on the Escambia in 1955, and is still collecting data from a study he installed in 1957. "The long-term silvicultural and fire ecology study sites provide 'living laboratories' available to other researches working to unravel some of the many fascinating mysteries lurking within what was once one of the most extensive forest ecosystems in North America."

Collaborators:

T.R. Miller Mill Company; Auburn University; Longleaf Alliance; Forest Service, Southern Region; U.S. Department of Defense; Tall Timbers Research Station; Jones Ecological Research Center; four State forestry agencies; Cyrene Turpentine Company; Eglin Air Force Base

For more information:

Escambia Experimental Forest: http://www.srs.fs.usda.gov/4111/experimental_forests.html

SRS Restoring and Managing Longleaf Pine Ecosystems unit: http://www.srs.fs.usda.gov/4111/

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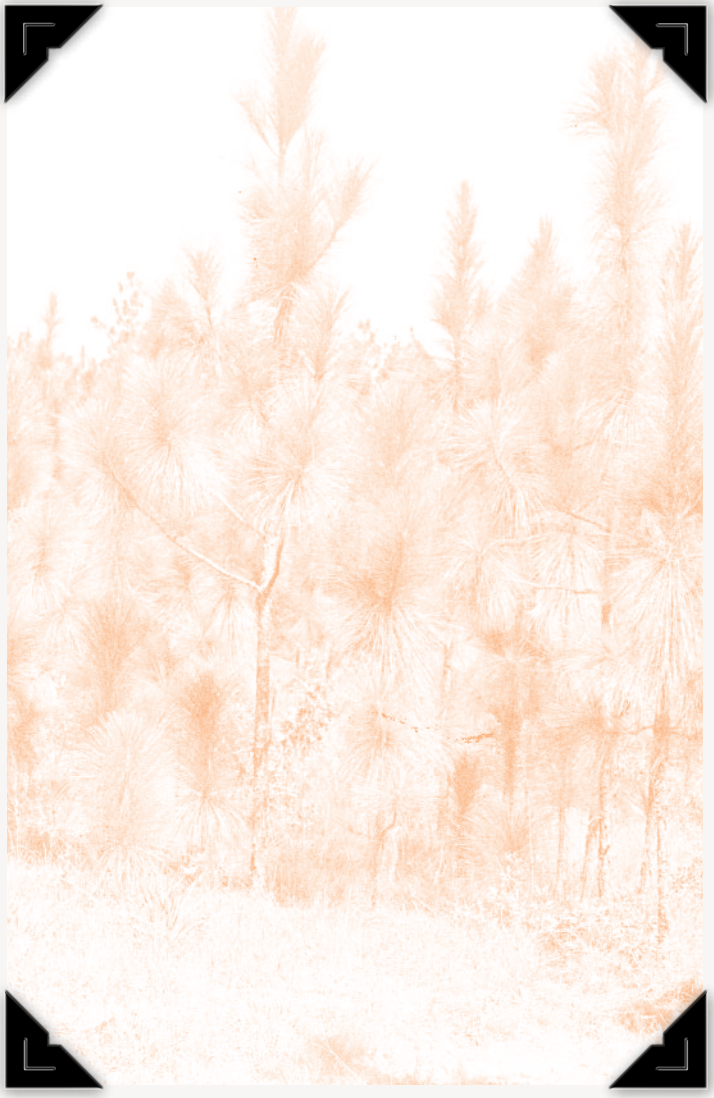

Longleaf pine in grass stage. (Forest Service photo)

Thinning study on the Escambia. (Forest Service photo)

Forty Acres: Making it work for landowners

After the Escambia was established in 1947, the land was surveyed and divided into 40-acre compartments. Two 40-acre studies were established as demonstrations for landowners.

The **Farm Forty Study** was designed to show what an average landowner could get off 40 acres of longleaf pine in a year without spending much effort or money. The acres were managed using the shelterwood method, resulting in open stands with large well-spaced seed trees. All the operations were those that could be done by the owner with average farm equipment. An annual field day was held to showcase all the products—poles, sawtimber, turpentine, and gum—that could be harvested from a 40-acre woodlot in 1 year. Each fall all the harvested products except naval stores (represented by empty barrels) were stacked on a yard for visitors to see.

The 40-acre **Investment Forest Study** was set up at the same time to offer practical management guidance to the typical investment owner. To help investors evaluate profits from longleaf pine stands, records were kept of the costs of activities such as timber marking, maintenance of roads and boundaries, and prescribed burning. Logging was done by company contract crews and management activities by station personnel.

60 Years on the Farm 40

John Kush, research fellow at the Auburn University Longleaf Pine Stand Dynamics Laboratory, and **Becky Barlow**, assistant professor at the Auburn School of Forestry and Wildlife Sciences, recently spent almost 3 days filming the story of the Escambia, including extensive interviews with SRS emeritus researcher **Bill Boyer**. They plan to produce three to four videos for use by landowners, agencies, and the general public. The first of these, "60 Years on the 'Farm 40'," can be viewed at www.srs.fs.usda.gov/news/377.

For more information:

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Each year products from the Farm Forty Study were stacked on a yard to demonstrate to landowners what they could harvest in a year from a 40-acre woodlot. (Forest Service photo)

Longleaf Pine Seed Problems

Do the Math

In 1963, from his work on the Escambia, SRS researcher **Bill Boyer** developed the guide to longleaf pine seed dispersal that became one of the foundations for the natural regeneration of the species. Natural regeneration—literally allowing seedlings to sprout wherever seeds fall—seems the intuitive choice for replanting longleaf pine, but compared to other pines, longleaf ranks very low when it comes to producing seed. It takes 3 years for seed to develop after the tree flowers. Seed crops adequate enough to regenerate a stand may come once every 5 or 7 years.

In 1997, after more than 40 years of working with longleaf, Boyer wrote: "Longleaf cone crops are highly variable from year-to-year, and also from place to place. Given a receptive seedbed, 360 cones per acre are needed, on average, just to obtain the first seedling. A minimum of 750 cones per acre is usually needed for acceptable regeneration. Given 25 residual seed trees per acre in a shelterwood stand, it takes an average of 30 cones per tree to reach this minimum. Cone crops of this size or larger are uncommon throughout much of the longleaf region, and are erratic in their occurrence .... In most years, cone crops will average less than 10 cones per mature seed tree." For marginal stands, this means little or no regeneration.

In 1966, Boyer helped set up a regionwide study that continues to monitor flowering and count cones and seeds from mature longleaf pine trees on sites ranging from North Carolina to Louisiana, as well as on the Escambia. Analyzing data from the extensive database developed for this project, scientists found something intriguing: over the last two decades (1986 to 2008), cone production on the Escambia has more than doubled when compared to that of the preceding 20 years. Researchers are not yet sure why, whether it has to do with tree age or changes in climate.

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Boyer, W.D. 1963. **Longleaf pine seed dispersal.** Res. Note SO–3. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 2 p.

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Compared to other pines, longleaf ranks very low when it comes to producing seed. (Forest Service photo)

The Palustris and Longleaf Pine

What if natural regeneration isn't an option

by Zoë Hoyle

In 1935, when the Forest Service established the 7,500-acre **Palustris Experimental Forest** (Palustris) on the **Kisatchie National Forest**, researchers faced different challenges than those they found later on the Escambia. The Palustris, chosen as representative of southwestern Louisiana and east Texas, had been denuded by railroad and cable logging in the early part of the century. Later attempts to farm on the shallow, poorly drained soil had failed, and once magnificent longleaf pine forests either were gone or existed as sparse stands invaded by scrubby hardwoods and feral hogs.

There simply weren't enough mature longleaf pine trees left to support natural regeneration on the Palustris. Early researchers started out by introducing loblolly and slash pines to the cutover land, later reestablishing the more disturbance-resilient longleaf pines. In stands where there were no mature trees to shelter natural regeneration, researchers transplanted bare-root longleaf pine seedlings, testing different treatments to find the best methods to help them survive.

Though effective, planting bare-root seedlings proved too labor intensive and expensive for the region's landowners, who needed to reforest large areas of cutover land. **Philip Wakeley** and other early pioneers began new experiments on direct seeding. The cone and seed studies of southern pines that Wakeley started in the early years on the Palustris have been used around the world to reforest seemingly barren landscapes. As the stands in the experimental forest grew, researchers studied thinning methods to increase the growth of desirable pine trees and prescribed fire to reduce competition from fast growing hardwoods.

The cone and seed studies of southern pines that Wakeley started in the early years on the Palustris have been used around the world to reforest seemingly barren landscapes.

In the 1960s, when SRS researcher (later, project leader) **James (Jim) Barnett** started working on the Palustris, the focus was still on direct seeding for longleaf pine reforestation. Seeds themselves were still a problem. Landowners and managers had tried unsuccessfully to use the same collection and storage methods for longleaf that were used for other pine species, but in this area—as most others—longleaf proved to be an anomaly. Barnett was instrumental in developing methods for collecting, storing, and planting longleaf pine seeds that increased viability exponentially, but many landowners who planted longleaf from seed were still not seeing good survival rates. By the end of the 1960s, there was a shift back to bare-root seedlings, and Barnett began planting bare-root seedlings on the Palustris, testing them for survival.

Containerize to Thrive

Bare-root seedlings are grown in a nursery bed. When they're large enough to be transplanted, the seedlings are lifted from the bed and the soil removed from the roots before the seedlings are packaged for shipping. Though the method is cost-effective, Barnett and fellow researchers found that only 40 to 60 percent of bare-root seedlings survived planting—not very attractive odds for landowners trying to reestablish longleaf pine stands.

Barnett began experimenting with growing longleaf pine seedlings in containers. With other trees, sapling survival is usually improved by growing seedlings in containers, but when Barnett started his studies in the 1970s, it was widely believed that longleaf could not be grown in containers. In contrast, Barnett's studies showed survival rates of container-grown seedlings of 80 to 90 percent, almost double those of bare-root seedlings. Container seedlings also showed superior growth and survival under adverse conditions. "Longleaf is the only pine species that actually needs containers for its seeds and seedlings," says Barnett. "Almost everything you do with longleaf is different than other pine species, more challenging and more interesting."

Barnett developed—and though retired, continues to update—what he still calls "interim" guidelines for container-grown seedlings. His work has proved invaluable for both

(continued on page 32)

The Palustris

(continued form page 31)

growers and managers as prices for both longleaf pine seeds and seedlings have soared over the decades. In 2002, he published research on another improvement—adding minute amounts of copper to the inside of containers to improve root structure and weight. The copper-treated cells in the containers arrest the growth of lateral roots they come in contact with. This produces a bigger taproot and roots that branch out more naturally. (For more, see *Containers, Copper, and Roots* on page 33.)

In the 1930s, researchers established studies on the Palustris to compare burned with unburned acres of longleaf pine forests and to evaluate growth and development in relation to different management treatments. Two of these original stands have been continuously managed since that time, providing the long-term datasets that form the basis for the growth and prediction models land managers need to grow longleaf pine more successfully for multiple purposes.

SRS plant physiologist **Mary Anne Sword Sayer** continues to test the effects of season of prescribed fire on longleaf pine, looking at how season of fire affects sapling growth and leaf area and root carbohydrate dynamics. She is also looking at how drought and prescribed burning interact to affect these and other variables.

SRS research forester **Dave Haywood** and Sword Sayer also use Palustris plots to study how management practices as diverse as weed control, fertilization, burning, and pine straw gathering and mulching affect the growth and productivity of longleaf pine stands. Their results are important to land managers who want to manage for income from timber as well as other uses, but the greatest application of results from the long-term experiments on the Palustris is towards the restoration of the magnificent longleaf pine ecosystem.

For more information:

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Mary Anne Sword Sayer: 318–473–7275 or msword@fs.fed.us

Recommended reading:

Barnett, J.P.; Hainds, M.J.; Hernandez, G.A. 2002. **Interim guidelines for growing longleaf seedlings in containers.** Gen. Tech. Rep. SRS–60. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 3 p.

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Grazing cattle was once common in the pine forests of Louisiana. Responding to landowner needs for additional income while establishing longleaf pine stands, researchers at the Palustris started grazing cattle on some plots, measuring both seasonal weight gain in the animals and the ecological effects of grazing on the trees. (Forest Service photo)

Containers, Copper, and Roots

Do the types of container used to grow longleaf pine seedlings really make that much difference? Studies on the **Palustris Experimental Forest** (Palustris) would affirm that indeed they do.

Some 75 million longleaf pine seedlings are produced every year; a large number of these are grown in containers. Demand for seedlings has increased as landowners and managers become more aware of the advantages of planting longleaf pine in areas prone to disturbances such as fires and hurricanes. Container-grown seedlings are twice as expensive as bare-root seedlings, so managers reasonably expect a higher long-term survival rate from seedlings grown in containers.

In 2003, when SRS research forester **Dave Haywood** and plant physiologist **Mary Anne Sword Sayer** were working on the Palustris, they noticed that an unusual number of longleaf pine saplings had toppled when wind storms came through. They heard similar reports from industry and from university scientists across the southern region. Comparing notes, researchers suspected that the saplings were container-grown, and that their taproots were too deformed or their lateral roots too unevenly distributed around the taproot to hold against the wind.

SRS plant physiologist **Susana Sung** decided to go back to plots on the Palustris where artificial regeneration experiments had been established three decades before. In 2006, Sung started digging up longleaf pine trees 12 to 35 years old to look more closely at their root systems. She sampled trees regenerated by direct seeding, bare-root seedlings, and container-grown seedlings.

"As expected, trees from direct seeding had the longest taproots and more evenly distributed woody lateral roots," says Sung. "Container-grown seedlings had the shortest taproots and the most uneven distribution of woody lateral roots."

From these and other results, Sung recommended that those growing seedlings focus more on root development—and that copper-treated containers, though more expensive, offer the most "bang for the buck." Copper (in miniscule amounts) essentially "zaps" roots as they grow towards the container walls; however, once these seedlings are outplanted, the lateral roots resume growing into their natural architecture.

What Sung found from digging up old studies reinforced findings from a study Sword Sayer and Haywood had installed on the Palustris in 2004 in an effort to improve container stock for hurricane zones. They found an increase in taproot weight, a change in lateral root morphology, and a shift in root growth potential along the outside of root plugs in response to copper. By year three, the saplings from the copper-treated containers were larger, with increases in height and diameter at ground level relative to container size.

So what's the latest recommendation? "Use a copper-coated container that's at least 5.7 cubic inches—a medium size—for longleaf pine seedlings," says Sung. "Our research shows that the copper coating supports accelerated growth of longleaf seedlings out of the grass stage and less of the lateral root spiraling that can lead to saplings toppling from high wind conditions."

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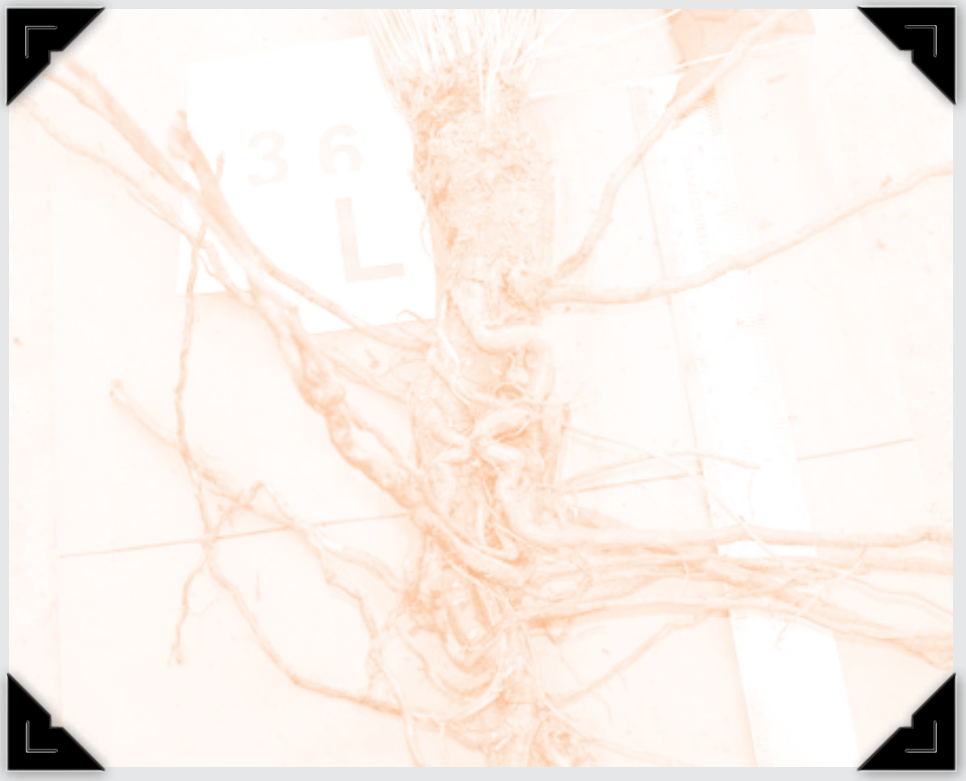

Studies on longleaf pine roots by Susana Sung have led to new guidelines for seedling containers. (Forest Service photo)

Pine Straw

Recognizing that the needles from longleaf pine—the pine straw—could in some markets actually be worth more than the timber, SRS research forester Dave Haywood and other researchers began testing the effects of different pine straw harvesting methods on the soil and understory ecology of longleaf pine stands. Haywood wanted to help landowners maximize income (as much as $100 to $400 an acre annually) from harvesting pine straw while keeping stands healthy. A pine straw harvesting guide was developed with the Arkansas Cooperative Extension Service. (Forest Service photo)

The Harrison

Longleaf genetics come of age

Located in the lower Coastal Plain in southeastern Mississippi, the **Harrison Experimental Forest** (Harrison) was established on the **Desoto National Forest** in 1934. By that time, vast stands of southern pines, mostly longleaf pine, had been cut from the estimated 31 million acres that made up the southern Coastal Plain forest. Located just north of Gulfport, MS, the 4,111-acre experimental forest has provided critical information about the genetics of longleaf pine for over half a century.

In 1955, the **SRS Southern Institute of Forest Genetics** (SIFG) was located on the Harrison, with research studies focused on forest genetics and pathology. SIFG research on the genetics of growth, form, and pest resistance of forest trees has guided tree improvement programs across the South. Studies on longleaf pine were prominent from the very beginning. Early selection studies by longleaf pine research pioneer **Philip Wakeley** were followed by a multigenerational longleaf pine breeding program based on his selections. Geographic seed source research and resin yield studies in relation to southern pine beetle resistance followed, involving emeritus scientists **Ron Schmidtling** and **Jim Roberds**, respectively.

Molecular biology and genetic mapping techniques have ushered in a whole new era of research on the Harrison. The location of SIFG on the experimental forest provides the unique capacity to combine these new tools with experimental plots and data that span decades to address issues that affect longleaf pine growth.

The fungus *Scirrhia acicola*, better known as brown spot needle blight, attacks 28 species of pines, but it inflicts the most damage on the longleaf pine, killing seedlings in the earliest stage of their development. Through work on the Harrison, SIFG researchers led by project leader **Dana Nelson** combine the latest in genetic mapping tools with classic genetic breeding to give longleaf seedlings a better shot at surviving the blight.

SIFG research geneticist **Tom Kubisiak** contributes expertise in genetic mapping, using statistical analysis to locate sites on the pine genome that affect traits like early height growth and blight resistance. **Nurul Faridi**, SIFG research cytogeneticist located at College Station, TX, uses fluorescent in situ hybridization, or FISH—a molecular biology tool that allows scientists to mark specific pieces of genetic code with fluorescent tags—to locate genes in the longleaf pine genome that might affect resistance to blight.

Hurricanes and Climate Change

Experimental plots were installed on the Harrison in 1961 to test the responses of three different pine species—longleaf, loblolly, and slash—to fertilization. Along with a surprisingly strong response to one-time fertilization in all three species, the experiments showed that after about 25 years longleaf pine catches up with loblolly pine. In 1999, at mean age 39, mean timber volume per acre was actually greatest in the longleaf pine plots.

When Hurricane Katrina hit the Harrison in 2005, the experimental plots took a beating. In 2006, researchers measured the damage, comparing their data to 1999 records. They found that the damage from Katrina was over 30 percent greater in the loblolly pine plots than in the longleaf pine and slash pine plots. Findings from the damaged plots have provided important information for land managers trying to decide how to replant hurricane-damaged areas along the Gulf Coast while taking into

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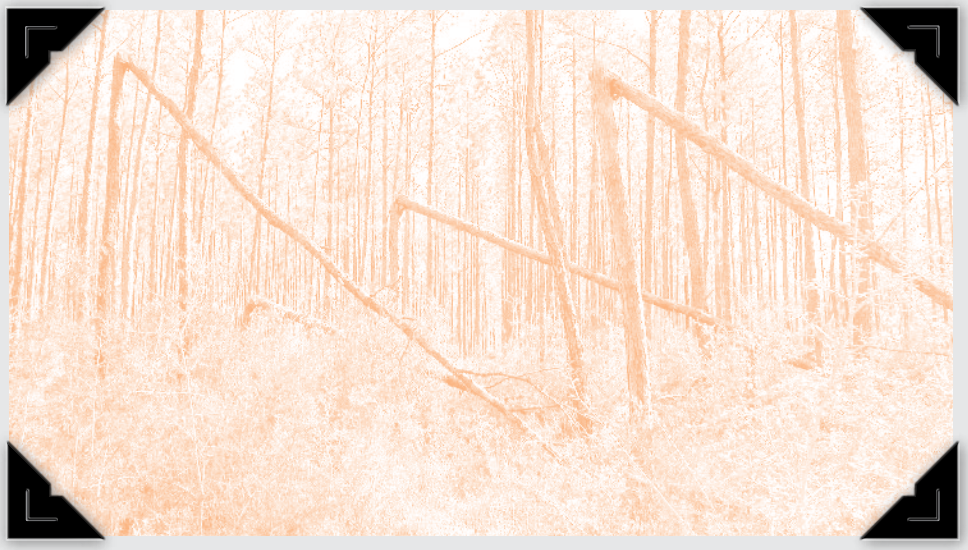

When Hurricane Katrina hit the Harrison in 2005, longleaf pine plots sustained 30 percent less damage than loblolly pine plots. (Forest Service photo by John Butnor)

The Harrison

(continued from page 35)

account the increased storm activity predicted under global climate change.

During the same period, SRS research physiologist **Kurt Johnsen** and his **Southern Institute of Forest Ecosystems Biology** team based in North Carolina started studying the Harrison plots as part of their research on carbon sequestration and tree species adaptation to climate change. In spring 2008, Johnsen, research biological scientist **Chris Maier**, and plant physiologist **John Butnor** drove out to the Harrison to map tree roots and measure soil respiration for research on the differences in carbon storage among the three pine species.

Johnsen and his team also started designing and preparing a companion study in collaboration with SIFG researchers. (All are part of the larger **SRS Forest Genetics and Ecosystem Biology** unit led by Nelson.) Seedlings for the new study will be grown from seeds harvested from the 1961 study and from genetically improved seeds. Various fertilization and prescribed fire treatments will be applied, and instruments to measure carbon efflux installed on the site so that scientists can study the interplay among genetics, silviculture treatments, and carbon sequestration. Together, the old and new studies will provide land managers the science-based knowledge they will need to manage and adapt Coastal Plain forests as the climate changes over the next century. *—ZH*

Collaborators:

Auburn University, Clemson University, University of Florida, Cornell University, Oklahoma State University, Mississippi State University, Louisiana State University, International Paper Company, North Carolina State University, Texas A&M University, University of Georgia

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The Chipola
A unique sandhill site

Located in the sandhills of the Florida Panhandle, the **Chipola Experimental Forest** (Chipola) was established in 1952 on privately owned land under a 99-year lease to the **Southern Forest Experiment Station** (now SRS), **International Paper Company**, and **Hardaway Contracting Company**. The two companies requested the cooperative arrangement with the Forest Service to enable research on restoring the cutover sandhills of the region then known as "Deserts in the Rain."

About 8 million acres of sandhills are scattered across the Coastal Plain of the Southeastern United States. A significant feature of central and northwest Florida, sandhills areas are also found in Georgia, South Carolina, and North Carolina.

Before the 1900s, the Chipola was a typical Florida sandhills site, with an overstory of longleaf pine trees, a midstory of scattered scrub oaks, and an understory of grasses and other herbaceous plants. Most of the longleaf pines on the site were logged in the 1900s, leaving only a few scattered patches and isolated trees. By the 1950s, when the experimental forest was established, most of the upland sites had been taken over by scrub oak and wiregrass.

Until 1981, Forest Service and cooperator research was conducted through a unit based in Marianna, FL. After the unit was closed in 1982, the 2,760-acre experimental forest was reduced to 1,250 acres, then reduced again in the 1990s. In 2004, SRS purchased the 940 acres that currently make up the Chipola.

Early research on the Chipola included species comparison trials on various conifers, including Choctawhatchee sand pine, a native pine species growing almost exclusively in northwest Florida and extreme southeast Alabama. Findings showed that only Choctawhatchee sand pine and longleaf pine can be grown successfully on the deep sand soils that typify the sandhills. Almost all of the current knowledge on how to establish and manage Choctawhatchee sand pine comes from research on the experimental forest.

In the 1990s, land managers in the Florida Panhandle area noted a large decline in wiregrass—a dominant understory plant in the longleaf pine ecosystem—due to mechanical site preparation methods. SRS research plant ecologist **Kenneth Outcalt** used the research plots on the Chipola to address these concerns and to make specific recommendations to reduce soil disturbance and wiregrass mortality. *—ZH*

Research findings from the Chipola showed that Choctawhatchee sand pine and longleaf pine are the only conifers that can be grown successfully on sandhill soils. (Forest Service photo)

Bringing Productive Pine Forests to Ruined Land

From logging spoils to America's wood basket

by Carol Whitlock

Forest researchers tend to believe that long-term ecological studies are best implemented on lands with stable ownership, the type of opportunity which is offered by experimental forests on publicly owned lands. This was certainly true at the beginning of the 20th century when members of a brand-new profession—forestry—set out to establish a new generation of pine forests on land that was cutover, eroded by irresponsible logging, or abandoned after decades of cotton and tobacco growing and generations of subsistence farming.

This restoration effort was the primary responsibility of the **Southern Forest Experiment Station**, newly established by the Forest Service in 1926 to serve the Piedmont, Coastal Plain, and Mississippi River basins from offices in New Orleans—and predecessor to the **Southern Research Station**.

During the 1920s, new studies began with great enthusiasm and heartfelt commitment to cooperation on forest industry holdings in Louisiana, Mississippi, and Florida. These earliest pine experiments contained most of the "seeds" of a research program that continues to provide scientific information and to define best management practices for forest lands held by succeeding generations of landowners, including our national forests, and managed by forestry professionals.

The investigators in these early studies were interested in forest products, and measured growth and yield in managed and unmanaged stands for the four predominant pine species. They studied the effects of fire on range capacity and the interacting effects of fire and cattle grazing on longleaf reproduction. They examined the effects of thinning second-growth stands of loblolly and shortleaf pines. They observed fire impacts on stems and foliage. And they developed new techniques for extracting resin from live pine trees in a vain effort to sustain the naval stores industry that produced turpentine, pitch, rosin, tar, linoleum, and other products from the 1700s to 1970—an industry doomed by the ability of the petrochemical industry to manufacture these products far more inexpensively.

Trees take a lot more time to mature than corn or wheat, and experiments on forest responses to new management practices were more often measured in decades than months or years. In the early days, new career opportunities for scientists with universities and industry, and changes in land ownership, often meant that promising lines of research were abandoned. It was not until the 1930s, when the new concept of "experimental forests" led to parcels of national forest and industry lands leased long-term to the Government for the conduct of research. The establishment of experimental forests made it possible to invest in long-term studies with statistical rigor and continuity of measurements that were able to withstand the inevitable shifts in personnel and in the priorities of policy makers, both in government headquarters offices and corporate boardrooms.

At the Crossett in Arkansas, the Harrison in Mississippi, the Hitchiti in Georgia, the Olustee in Florida, the Palustris in Louisiana, and the Calhoun in South Carolina, forest researchers put together the pieces of a forest management strategy for southern pines, a strategy that transformed the South from a state of depletion to a region that now produces more timber than any other part of the United States and, indeed, any other country on the planet.

Recommended reading:

Wakeley, Philip C. **A biased history of the Southern Forest Experimental Station through fiscal year 1933.** 289 p. On file: ??

Picking cotton on the Calhoun Experimental Forest in the 1950s. (Forest Service photo)

The Crossett

Regrowth starts in the West

Since its establishment in 1934, the **Crossett Experimental Forest** (Crossett) has been the repository of silvicultural alternatives to the intensive plantation methods that dominate industrial forestry on the Coastal Plain. The hidden secret of southern forestry is that Coastal Plain loblolly-shortleaf pine is the Nation's most pliable forest type, able to be sustainably managed using even-aged and uneven-aged silvicultural systems that rely on natural regeneration—methods that find tremendous interest on private family forest lands as well as public lands. There's no better place in the South to see this variety of successful practice than the Crossett, venerated for its role as a field laboratory and demonstration site for good forest management.

The **Crossett Lumber Company**, later acquired by Georgia-Pacific, originally deeded the land to the **Southern Forest Experiment Station** (now SRS) in a 50-year agreement that committed the Station to return an amount of timber equal to what was present on the forest at the time of the agreement. Crossett founder **Russ Reynolds** succeeded in delivering on the Station's commitment and in leaving the forest better stocked than it was at the time of the take over. With the rise of interest in plantation forestry in the 1960s, the work at Crossett was thought for a while to be out of date. But time has shown the wisdom behind the silvicultural tactics at Crossett—they provide foresters with the diversity of management tools needed to meet the diversity of forest ownership goals in the 21st century.

The siloicultural tactics developed at the Crossett provide foresters with the diversity of management tools needed to meet the diversity of ownership goals of the 21st century. (Forest Service photo)

Since those early days, the Crossett has been without peer as a research and demonstration forest, with visitors numbering in the thousands over the past five decades. Foresters, landowners, students, and teachers have visited the **Farm Forestry Forty Demonstration Area** to learn about the selection method in southern pines in stands that have now been managed using that method for seven decades. These outreach efforts have also been instrumental in helping southern national forests move away from intensive plantations and toward management that relies on natural regeneration, and that maintains continuous forest cover.

The Crossett staff maintains additional research studies that demonstrate different even-aged and uneven-aged cutting methods that rely on natural regeneration, rehabilitation of understocked stands, development of tools to create managed old-growth stands, as well as the use of prescribed burning to control competing vegetation. The 80-acre **Reynolds Research Natural Area** is used to study the ecology of stand development in the absence of management.

Each spring the Crossett staff sponsors a Forestry Field Day to help foresters and private landowners learn about cutting-edge research and technological developments designed to improve low-cost natural stand management. In addition, Crossett scientists are responsible for the southern pine module of the **National Advanced Silviculture Program**, whereby Forest Service field foresters are certified for silvicultural decisions. These science delivery activities are typically cosponsored by the Arkansas Forestry Commission, the Arkansas Cooperative Extension Service, and the School of Forest Resources at the University of Arkansas at Monticello.

—JG

Recommended reading:

Bragg, D.C.; Shelton, M.G.; Guldin, J.M. 2007. **Restoring old-growth southern pine ecosystems: strategic lessons from long-term silvicultural research.** In: Deal, Robert L., tech. ed. Integrated restoration of forested ecosystems to achieve multiresource benefits: Proceedings of the 2007 national silviculture workshop. Gen. Tech. Rep. PNW–GTR–733. Portland, OR: U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station: 211–224.

Cain, M.D.; Shelton, M.G. 1996. **The R.R. Reynolds Research Natural Area in southeastern Arkansas: a 56-year study in pine-hardwood sustainability.** Journal of Sustainable Forestry. 3(4): 59–74.

Reynolds, R.R. 1980. **The Crossett story: the beginning of forestry in southern Arkansas and northern Louisiana.** Gen. Tech. Rep. SO–32. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 40 p.

Each spring the Crossett staff sponsors a Forestry Field Day to help foresters and landowners learn about cutting-edge research designed to improve low-cost natural stand management. (Forest Service photo)

The Harrison

Seed for reestablishing southern pine forests

Soon after the 1933 establishment of the **DeSoto National Forest** in Mississippi, the Federal Government designated a 4,111-acre portion as the **Harrison Experimental Forest** (Harrison). The site was selected because it represented the 3 million acres of clearcut and second-growth forests in the State as well as the 31 million acres of coastal land with similar soils and topography. The scientists stationed at the Harrison fell under the direction of the Mississippi Bureau of Plant Industry but worked in cooperation with the **Southern Forest Experiment Station** (SFES).

Some of the earliest studies on the Harrison involved fire behavior and wood treatment. Scientists introduced water spray as a preprocessing preservative, a technique that is still used in sawmills today. Early trials of fence posts treated with various preservatives have been revisited every year since 1939.

The problems with planting and growing trees and reestablishing forests soon became the primary focus for research at the Harrison. The **Southwide Southern Pine Seed Source Study** was started on the experimental forest in 1951, and continues today. The study has provided seed source guidelines to managers and landowners for more than 50 years.

In 1953, SFES assumed responsibility for the facility. Three years later, the Harrison became headquarters for the **SRS Southern Institute of Forest Genetics**, whose research on the inheritance of growth, form, and pest resistance has since guided tree improvement programs across the South. (See also page 35).

Long after the seed source study results were reported, the plantings for that study continue to be useful for new research, such as efforts to determine the genetic basis of pest resistance, variation in wood quality, and effects of climate on pine growth. Most recently, Harrison's scientists have begun evaluating the original genetic variation of the plantings with a vision toward long-term gene preservation. *—CW*

The Southwide Southern Pine Seed Source Study started on the Harrison in 1951 still provides guidelines to managers and landowners across the South. (Forest Service photo)

The Stephen F. Austin

Productivity is more than just trees

Located 7 miles west of Nacogdoches, TX, the 2,560-acre **Stephen F. Austin Experimental Forest** (Stephen F. Austin) was established by an act of Congress in 1945. For its first 15 years, the experimental forest was primarily used for research that improved methods for growing loblolly and shortleaf pine. In 1949, 40 acres were set aside as a demonstration forest where landowners could learn how to manage small lots for timber production as part of the larger **Forest Service Farm Forest 40** project.

In 1961, scientists at the Forest Service research unit in Nacogdoches changed the focus of research on the Stephen F. Austin to wildlife, with initial studies focused on game species such as white-tailed deer, which were scarce in east Texas at that time. Over the years, the research program has moved toward nongame species, including threatened, endangered, or sensitive species.

SRS researchers **Craig Rudolph** and **Dan Saenz** have conducted life history studies on timber rattlesnakes, amphibians, turtles, and several woodpecker species on the experimental forest, these last led by **Richard (Dick) Conner**, emeritus researcher. Students from the nearby Stephen F. Austin University (SFA) have added decades of studies on birds, reptiles, amphibians, rodents, insects, and arthropods.

The USDA Natural Resources Conservation Service has maintained the **East Texas Plant Materials Center** on the Stephen F. Austin since 1987. The center was started to develop improved materials for livestock forage and wildlife habitat enhancement, and, through a cooperative arrangement with SRS, can use up to 70 acres of the experimental forest to plant and test various plant materials.

Over the years, the Stephen F. Austin has become increasing attractive as an outdoor classroom for SFA students, for conservation education with the general public, and as a recreation area. In 1990, management objectives for the experimental forest were expanded to include educational and recreational opportunities for the general public. In 1992, then SRS project leader **Ron Thill** developed a plan to establish an interpretive trail system on the forest. **The Stephen F. Austin Interpretive Trail System**, which is wheelchair accessible, was completed in 1997 as a collaborative project among SRS, Region 8 of the National Forest System, the National Forest and Grasslands of Texas, the SFA College of Forestry, and volunteers from local organizations. *—ZH*

Interpretive trail on the Stephen F. Austin Experimental Forest. (Forest Service photo)

Recommended reading:

Russell, C.C.; Thill, R.E.; Kulhavy, D.L. 2002. **The Stephen F. Austin experimental forest.** East Texas Historical Journal. XL(2): 40–52.

The Calhoun

Restoring soil on wasted lands

Until the middle of the 20th century, forest researchers were mostly concerned with what could be done above the ground—growing trees, protecting them from insects and diseases, maximizing productivity, and regenerating stands after harvesting. It was not until 1947, when the **Calhoun Experimental Forest** (Calhoun) was established on the **Sumter National Forest** in the Piedmont of South Carolina, that soil studies began in earnest. The 2,078-acre site for the Calhoun was chosen because it represented the poorest Piedmont conditions, the "worst of the worst." The hope was that studies at the Calhoun could inform efforts to reforest ruined lands across the Piedmont and the South.

> ***"Long-term Calhoun studies demonstrate like few others how humanity transforms soil."*** —Dan Richter

Under **Louis Metz**, Calhoun's first director, and with later guidance from **Carol Wells**, the Calhoun staff began a program of work aimed at soil improvement. According to Metz, their goal was "to find the cheapest, quickest, most effective ways of speeding tree growth, increasing plant nutrients, and improving soil structure so that the land stores water for plant use."

To that end, they installed the **Calhoun Long-Term Soil Ecosystem Experiment**, regarded by many as one of the finest long-term ecological studies in the world. Started in 1957 by Metz and expanded by Wells in the 1960s, the versatility of the study has allowed scientists to address a series of important issues. At first, the experiment consisted of planting pine seedlings at different densities to determine how best to grow pine forests on soil exhausted by farming, with the aim of providing the information needed to improve soil and watersheds across the South. Later, as the stands grew, they provided long-term data that informed new studies of tree and stand dynamics, biomass, and ecosystem productivity.

The soil sample archive kept since the first experiments on the Calhoun enable it to serve as one of the few sites in the world where chemical changes in soil over decades can be directly observed. In the 1980s, data from the Calhoun provided direct evidence of acid rain effects on soil. Today the same resource is providing data on carbon sequestration from over 40 years of direct observation of plant biomass, forest floor, and mineral soil.

The Calhoun is now managed collaboratively between **Duke University** and SRS. SRS research ecologist and science team leader **Mac Callaham** works with Duke soil scientist **Dan Richter** to coordinate studies on a site that provides a rare opportunity for long-term observations on soil response to degradation, restoration, and sustainability. *—ZH*

Recommended reading:

Richter, D.D.; Callaham, M.A.; Markewitz, D.; Vilgalys, R. 2007. **Understanding ecosystem change at the Calhoun Experimental Forest's long-term soil experiment.** Spec. Publ. New Haven, CT: Yale University. 11 p.

Extreme soil erosion on the Calhoun Experimental Forest led to reforestation in the 1950s. (Forest Service photo)

Pine plantation has replaced old cotton fields on the Calhoun Experimental Forest. (Forest Service photo)

Why Termites?

SRS experimental forests and termiticide registration

Termites cause an estimated $5 billion in damages in the United States every year. Most homeowners view termites as pests to be eliminated immediately, that annual termite inspection a necessity. In the South, where termite damage is legendary, proof of treatment for the insects is often required before a home can be sold.

Many people, assuming that termites are just urban or suburban pests, are surprised to learn that the Forest Service does termite research, but termites are really forest insects whose turf humans have invaded; they're just doing what they've always done as beneficial forest insects—decomposing wood, recycling carbon into soil and litter.

Today, the termite team based in the **SRS Insects, Diseases, and Invasive Plants** unit in Starkville, MS, is responsible for testing all candidate termiticides (pesticides specifically used to kill termites) to be marketed in the United States. The program got its start in 1935 as the first insect research project in the **Southern Forest Experiment Station** (now SRS), with much of the early research conducted in cooperation with the U.S. military. The post-World War II housing boom and the emerging development of synthetic insecticides also contributed to a need for systematic termite research. Because forests are the native habitat for termites, it seemed logical for the Forest Service to get involved. In the 1940s, the Station pioneered research on the soil-applied termiticides that are routinely used today.

(continued on page 44)

Scientists based in Starkville, MS, "grow" termites in logs for research conducted on three experimental forests in the South. (Forest Service photo by Craig Bell)

Why Termites?

(continued from page 43)

In the United States, all termiticides must be registered by Federal and State regulatory agencies. In 1947, the U.S. Department of Agriculture was assigned pesticide registration under the Federal Insecticide, Fungicide, and Rodenticide Act; in 1972, the act was revised and registration put under the authority of the U.S. Environmental Protection Agency. Termiticides became one of two groups of insecticides (along with public health insecticides) requiring efficacy data (how well they work) for registration. Because the Forest Service had developed an international reputation working on termites, and had the infrastructure, including land, to conduct the research, the Agency became involved with testing termiticides for Federal and State registration. This led to the present-day **Termiticide Testing Program**, which tests all termite pesticides marketed in the United States.

The SRS termite team, led by entomologist **Terry Wagner**, conducts testing research on four national field sites that also happen to be experimental forests and ranges: the Harrison in Mississippi, the Chipola in Florida, the Calhoun in South Carolina, and the Santa Rita Experimental Range in Arizona. All the sites but the last are owned by the Forest Service. (The Santa Rita is owned by the State of Arizona and managed by the University of Arizona.)

Using experimental forests and ranges to test termiticides has several advantages. Federal ownership means that long-term, stable experiments are possible with little chance of human-caused disturbance. (Hurricane Katrina, however, caused major damage on the Harrison in 2005 and even destroyed some termite research plots.)

The program tests repellent and nonrepellent termiticides, chemically impregnated barriers, and other termite control products. Products typically undergo 24 months of laboratory screening and 5 years of field testing prior to registration. Hundreds of products have been evaluated over the decades, most failing the registration process, which directly benefits the American public by keeping ineffective or unsafe products off the market.

In addition to providing efficacy data for product registration and labeling by Federal and State regulatory agencies, the termite team conducts other applied and basic research on termite biology, ecology, and behavior—both to determine the effects of control tactics on the insects and to better understand how these insects affect forest ecosystems and productivity. —ZK

Selected collaborators:

Chemical companies (registrants) and associations:
Responsible Industry for a Sound Environment (RISE), Bayer Environmental Science, BASF, Dow AgroSciences, DuPont, FMC, Sumitomo, Syngenta

Federal Agencies:
U.S. Department of Defense; U.S. Environmental Protection Agency; Federal Housing Administration; Federal Trade Commission; Forest Service (numerous experimental forests, national forests, and research units throughout the country); U.S. Department of Housing and Urban Development; U.S. Department of the Interior; U.S. Department of Agriculture Agricultural Research Service

Forest industry associations:
American Forest and Paper Association, American Wood Preservers' Association, National Association of Home Builders

Pest management industry and associations:
National Pest Management Association (NPMA), State Pest Management Associations, Orkin, Terminix

State regulatory agencies and associations:
Association of Structural Pest Control Regulatory Officials (ASPCRO), Florida Department of Agriculture, Indiana Office of State Chemist, Louisiana Department of Agriculture, Mississippi Department of Agriculture and Commerce, New Mexico Department of Agriculture, North Carolina Department of Agriculture, South Carolina Department of Pesticide Regulation

Universities:
Auburn University, Mississippi State University, University of Arizona

For more information:

Terry Wagner at 662-338-3112 or twagner01@fs.fed.us

Recommended reading:

Mulrooney, J.E.; Wagner, T.L.; Shelton, T.G. [and others]. 2007. **Historical review of termite activity at Forest Service termiticide test sites from 1971 to 2004.** Journal of Economic Entomology. 100(2): 488–494.

Wagner, T.L. 2003. **U.S. Forest Service termiticide tests.** Sociobiology. 41(1): 131–141.

Wagner, T.L.; Mulrooney, J.E.; Shelton, T.L. 2006. **Termiticide testing in full swing; USDA-FS's Mississippi site hit hard by Hurricane Katrina.** Pest Control. 55: 55–65.

The Hitchiti

Demonstrating the effects of prescribed burning

The 5,000-acre **Hitchiti Experimental Forest** (Hitchiti) is located about 65 miles southwest of Athens, GA, and is also the site of the **Brender Demonstration Forest** (Brender), a cooperative effort by SRS and the **Georgia Forestry Commission** to showcase pine management for nonindustrial private landowners.

In the 1930s, after 130 years of raising cotton, row crops, and livestock, Georgia farmers began to abandon their holdings due to a combination of depleted soils, drought, boll weevils, and poor market conditions. In 1939, to encourage a return to forests, Franklin D. Roosevelt established, by presidential proclamation, a 5,000-acre tract of land in Jones County for research on the silviculture of loblolly pine in the lower Piedmont. At the time the Hitchiti came into being, very little was known about establishing and managing loblolly pine on abandoned agricultural land in the region, and most people were pessimistic that the eroded and abandoned fields of the Piedmont would ever produce a stand worth harvesting and selling.

Fortunately, **Ernst Brender**, the scientist selected to lead research at the Hitchiti, was not one to be swayed by popular opinion. He and his staff discovered that high-quality wood could be produced rapidly on the old fields of the Hitchiti, a finding that foresters take for granted today, but one that prompted expansion of the forest industry in the Southeast and changed the landscape of the southern Piedmont.

(continued on page 46)

Research at the Hitchiti demonstrates the benefits of low-intensity prescribed fire on Piedmont sites. (Forest Service photo)

The Hitchiti

(continued from page 45)

In the late 1980s, two findings—that wood consumption would outstrip production and that the best opportunity for increased production was on the small nonindustrial stands of natural pine that typified the southern landscape—prompted the designation of the Hitchiti as a demonstration forest. In cooperation with the Georgia Forestry Commission and the Southern Industrial Forest Research Council, Hitchiti staff developed 25 plots to teach the principles of sound resource management. These plots provide a wide range of demonstrations, including clone banks and genetic improvement practices, red-cockaded woodpecker restoration, disease resistance, insect infestation suppression, clearcutting and uneven-aged management, postharvesting site preparation, and prescribed burning.

In 1987, a team of scientists led by SRS researcher **Dale Wade** established a series of plots on the Hitchiti to test the effects of season and frequency of prescribed burning on fuel reduction and Piedmont forest structure. They tested responses to six different treatments in a stand of naturally regenerated loblolly and shortleaf pines that had not been burned in over 50 years, tracking results by periodic measurements and surveys. A primary objective of the study was to influence public opinion about the benefits of frequent low-intensity prescribed fire versus fire exclusion.

Kenneth Outcalt, SRS research plant ecologist based in Athens, GA, took over management of the study when Wade retired in January 2003. "There are only a handful of studies like this in the South," says Outcalt. "This is the only one that I am aware of in the Piedmont, or in these mixed pine and hardwood stands." In 2004, the 15-year measurements were taken, which showed that even infrequent burning will control hardwood saplings that, once they make it into the midstory, are difficult to reduce in pine stands. Burning also increases the herbaceous cover in the understory, often a desirable goal in restoration and wildlife recovery efforts—and doesn't affect the large pines that house the red-cockaded woodpecker.

Because the plots are located along a major road—and next to the popular Hitchiti Hiking Trail—researchers and foresters use the studies to demonstrate the effects of prescribed burning to the public. The difference is readily apparent between plots where fire has been excluded and those that have been burned frequently at low intensities. A grant from the Joint Fire Science Program has funded a permanent outdoor display, individual treatment plot signs, and a fact sheet for a self-guided tour of the prescribed burn study.

As a demonstration forest, the Brender has an onsite manager, **John Moore**, and staff who provide outreach and tours to interested groups. The prescribed burn study is a featured stop on tours conducted for other researchers, land managers, foreign scientists, students, State and Federal employees, and the interested public. The experimental forest also includes an arboretum of native Georgia trees, two interpretive walking trails, and the Hitchiti Natural Area. *—CW*

Read more about the prescribed fire study at www.srs.fs.usda.gov/hitchiti/.

Collaborators:

Oconee National Forest, Brender Demonstration Forest, Georgia Forestry Commission, Southern Industrial Forest Research Council

For more information:

John Moore at 478-986-3914 or jmoore03@fs.fed.us

Recommended reading:

Brender, E.V. 1952. **A guide to the Hitchiti Forest Research Center.** Pap. SE–019. Asheville, NC: U.S. Department of Agriculture Forest Service, Southeastern Forest Experiment Station. 28 p.

Outcalt, K.W. 2006. **Managing composition of Piedmont forests with prescribed fire.** In: Proceedings 13th biennial southern silvicultural research conference. Gen. Tech. Rep. GTR–SRS–92. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 531.

Pine plantation on the Hitchiti Experimental Forest. (Forest Service photo)

The Olustee

From naval stores to southern pine genetics

The 3,135-acre **Olustee Experimental Forest** (Olustee), located in northeast Florida, was established in 1931. Part of the **Osceola National Forest**, the experimental forest served as the primary study site for a number of SRS research units for almost 60 years.

In the beginning, research on the Olustee focused primarily on naval stores, but its story is not complete without reference to **Keith Dorman**, who was sometimes called the Luther Burbank of forestry because of his pioneering efforts in the genetic improvement of southern pines. His work, which spanned 40 years, has enabled southern foresters to plant millions of acres of superior pines that grow faster, produce more wood, and are more resistant to disease.

Dorman's career with the Forest Service began on the Ottawa National Forest in the Upper Peninsula of Michigan. During the Second World War he transferred to Florida, where the Southern Station maintained a research unit in Lake City with field studies on the nearby Olustee. When Dorman arrived, "nearly every tree had a cat face," indicating a history of tapping pine resin for naval stores.

The term naval stores originally applied to the resin-based products used to waterproof wooden ships—turpentine, rosin, pitch, and tar. The use of the term evolved to encompass all products derived from pine sap, including those used today to produce soap, paint varnish,

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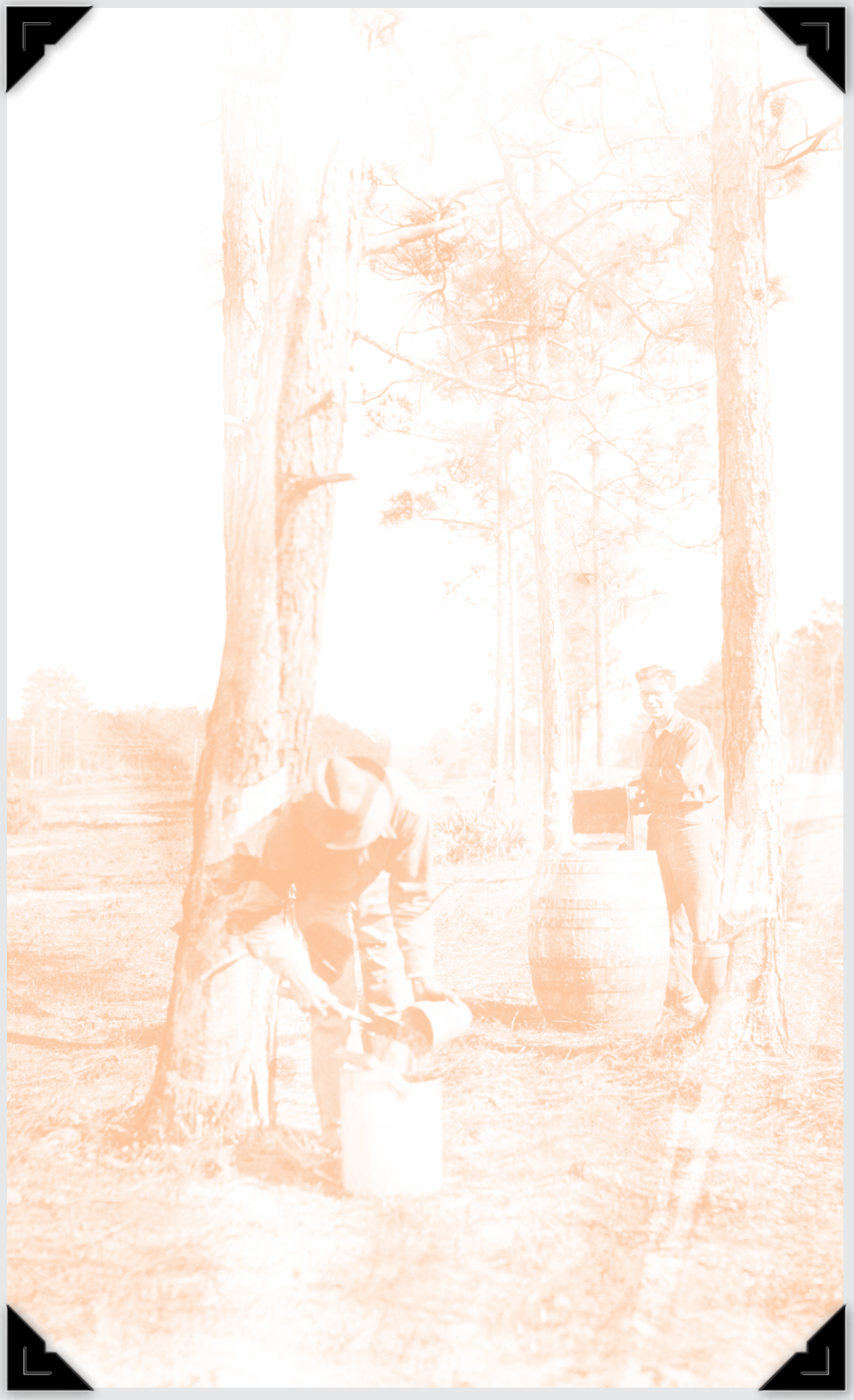


In its early days, research on the Olustee focused primarily on naval stores. (Forest Service photo courtesy Forest History Society, Durham, NC)

The Olustee

(continued from page 47)

lubricants, linoleum, and roofing materials.

To tap for naval stores, workers first gash the tree with a curved blade to remove the bark, placing an angled piece of galvanized tin below the 8-inch long, 1-inch wide "streak" to funnel the sap into a rectangular collecting cup. Each new streak goes in above the last, which gradually creates a vertical "cat face" that can extend 3 to 7 feet up the tree.

Spurred by high demand for naval stores during the war, Dorman embarked on a program of genetics research that was to continue for the rest of his career. "A basic task for any plant improvement program is the locating or selection of superior plants for breeding stock—those individuals which occur rarely throughout large numbers of their kind," wrote Dorman. "Once found, they may be used as parents in controlled breeding or as a source of material for rooting or grafting."

Dorman found a dozen trees that produced twice the resin as others and began breeding them. Within 5 years, groups of offspring from his selections grew twice as fast and produced twice the average resin yield, with individual trees producing four to five times the average.

These successes prompted Dorman to become interested in selecting for other qualities. He selected seeds from loblolly, longleaf, slash, and shortleaf pines, and began a creative breeding program that was the first to show inherent variations in growth, limb formation, specific gravity, and resistance to diseases such as fusiform rust. This work laid the foundation for the establishment of seed orchards throughout the South. Stands on the Olustee continue to be maintained for long-term studies and as a reservoir of genetic material for slash pine. *—CW*

Recommended reading:

Cooper, R.W. 1958. **A guide to the Olustee Experimental Forest.** Asheville, NC: Southeastern Forest Experiment Station. 26 p.

Dorman, Keith W. 1976. **The genetics and breeding of southern pines.** Agric. Handb. 471. Washington, DC: U.S. Department of Agriculture. 407 p.

Stands on the Olustee continue to be maintained as a reservoir of genetic material for slash pine. (Forest Service photo courtesy Forest History Society, Durham, NC)

Scull Shoals

The 4,500-acre **Scull Shoals Experimental Forest** (Scull Shoals) near Athens, GA, has been the site of silvicultural research studies since the 1930s. In 1959, when the experimental forest was officially designated part of the **Oconee National Forest**, studies were started on the role of fire in silviculture, the development of wildlife habitat, and the regeneration of the hardwood ecosystems of the southern Piedmont.

The ruins of Scull Shoals, once a major town between Atlanta and Savannah, are also on the site. Settled in 1784 on the Oconee River, at its height Scull Shoals included grist mills, sawmills, cotton gins, and a textile mill that employed over 600 people. The textile mill flourished until destroyed by a flood in 1887 that covered the town for 4 days and destroyed it economically. What was left became part of the Scull Shoals Experimental Forest in 1936, and the Oconee National Forest in 1959. It is now an historic recreation area on the Oconee National Forest.

Research at Scull Shoals, primarily from the 1960s and 1970s, provided a better understanding of littleleaf disease, which is caused by a complex of factors including the fungus *Phytophthora cinnamomi*, low soil nitrogen, and poor internal soil drainage. Littleleaf disease affects the shortleaf pines growing on the badly eroded land that once typified the southern Piedmont.

The feasibility of establishing intensively managed, short-rotation woody crop systems to produce fiber was also demonstrated by research at Scull Shoals in the late 1960s and early 1970s. In different locations across the United States, these types of systems are now being used to produce biofuels for local energy uses. *—ZK*

Southern Research Station headquarters when it was first built in 1982. (Forest Service photo)

New Products
from the Southern Research Station...

Natural Resources Inventory and Monitoring

1 Bentley, James W.; Johnson, Tony G. 2008. **Alabama harvest and utilization study, 2008.** Resour. Bull. SRS–141. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 24 p.

In 2008, a harvest and utilization study was conducted on 80 operations throughout Alabama. There were 2,100 total trees measured; 1,433 or 68 percent were softwood, while 667 or 32 percent were hardwood. Results from this study showed that 88 percent of the total softwood volume measured was utilized for a product, and 12 percent was left as logging residue. Seventy-five percent of the total hardwood volume measured was utilized for a product, while 25 percent was left as logging residue.

2 Bentley, James W.; Johnson, Tony G. 2008. **South Carolina harvest and utilization study, 2006.** Resour. Bull. SRS–140. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 24 p.

In 2006, a harvest and utilization study was conducted on 99 operations throughout South Carolina. There were 2,904 total trees measured; 1,763 or 61 percent were softwood, while 1,141 or 39 percent were hardwood. Results from this study showed that 87 percent of the total softwood volume measured was utilized for a product, and 13 percent was left as logging residue. Seventy-nine percent of the total hardwood volume measured was utilized for a product, while 21 percent was left as logging residue.

3 Johnson, Tony G.; Bentley, James W.; Howell, Michael. 2008. **Historical trends of timber product output in the South.** Resour. Bull. SRS–138. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 70 p.

Historical data of periodic canvasses of primary wood-using plants are presented for the 13 Southern States. They are Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. Cubic-foot and standard volume tables are presented for production only. Production is the sum of timber harvested and used within a State, plus all roundwood exported to other U.S. States.

4 Johnson, Tony G.; Bentley, James W.; Howell, Michael. 2008. **Oklahoma's timber industry—an assessment of timber product output and use, 2005.** Resour. Bull. SRS–136. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 28 p.

In 2005, roundwood output from Oklahoma's forests totaled 119 million cubic feet. Mill byproducts generated from primary manufacturers totaled 54 million cubic feet. Almost all plant residue was used primarily for fuel and fiber products. Saw logs were the leading roundwood product at 61 million cubic feet; pulpwood ranked second at 37 million cubic feet. There were 107 primary processing plants operating in Oklahoma in 2005. Receipts totaled 149 million cubic feet.

5 Johnson, Tony G.; Steppleton, Carolyn D.; Howell, Michael. 2008. **Trends in southern pulpwood production, 1953-2006.** Resour. Bull. SRS–139. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 53 p.

Southern pulpwood production has increased nearly fourfold from 16.2 million cords (43.9 million green tons) in 1953 to 64.7 million cords (170.9 million green tons) in 2006. Softwood roundwood production more than doubled in the same time period; however, softwood production expressed as a proportion of the total production has declined from 87 percent in 1953 to 49 percent in 2006. In contrast, hardwood roundwood production and production from residues of all types substantially increased. The average daily pulping capacity of southern mills climbed from 28,670 tons per day in 1953 to 125,093 tons per day in 2006. Southern mills accounted for 70 percent of the Nation's total pulping capacity in 2006.

6 McCollum, Joseph M.; Cochran, Jamie K.; Rose, Anita K. 2008. **A discrete global grid for photointerpretation.** Res. Pap. SRS–44. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 7 p.

The Forest Inventory and Analysis (FIA) program of the Forest Service, U.S. Department of Agriculture, collects its data in three phases. The first phase is collection of photointerpretation data or dot counts, the second phase is field collection of FIA plot data, and the third phase is collection of Forest Health Monitoring data. This paper describes the development of the phase 2 (P2) and phase 3 (P3) grids and discusses the creation of a new grid for phase 1 (P1), complete with an efficient indexing scheme, which is essentially equivalent to the historical dot count grids. The P2 grid consists of one field site per approximately 6,000 acres. To create the new P1 grid, we decomposed the P2 grid by a factor of 27 to obtain new

proposed P1 photointerpretation cells of about 220 acres. The new grid can be used for initial photointerpretation points to determine area estimates for forested land.

7 Oswalt, Christopher M. 2008. **Tennessee's forest land area was stable 1999-2005 but early successional forest area declined.** e-Res. Note SRS–15. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. [Not paged].

A new analysis of the most recent (2005) annualized moving average data for Tennessee indicates that the area of forest land in the State remained stable between 1999 and 2005. Although trends in forest land area vary from region to region within the State, Tennessee neither lost nor gained forest land between 1999 and 2005. However, Tennessee had more than 2.5 times as much early successional forest area in the early 1970s as in 2005. The decline in early successional forest area in Tennessee is a matter of concern.

Forest Ecosystem Restoration and Management

8 Abell, Margaret Stoughton. 1933. **A glimpse of the Appalachian Forest Experiment Station.** The Ames Forester. 21. 13–16.

The first woman forester employed at the Bent Creek Experimental Forest provides a brief review of the research conducted at the Appalachian Forest Experiment Station and the Bent Creek Experimental Forest. The author weaves a description of research projects and the cultural landscape as she discusses field work, wildlife, and the construction of Hardtimes Road.

9 Boerner, Ralph E.J.; Coates, Adam T. [*sic*]; Waldrop, Thomas A.; Yaussy, Daniel A. 2008. **Assessing ecosystem restoration alternatives in eastern deciduous forests: the view from belowground.** Restoration Ecology. 16(3): 425–434.

Both structural and functional approaches to restoration of eastern deciduous forests are becoming more common as recognition of the altered state of these ecosystems grows. In our study, structural restoration involves mechanically modifying the woody plant assemblage to a species composition, density, and community structure specified by the restoration goals. Functional restoration involves reintroducing dormant-season, low-severity fire at intervals consistent with the historical condition. Our approach was to quantify the effects of such restoration treatments on soil organic carbon and soil microbial activity, as these are both conservative ecosystem attributes and not ones explicitly targeted by the restoration treatments themselves. Fire, mechanical thinning, and their combination all initially resulted in reduced soil organic carbon (C) content, C to nitrogen (N) ratio, and overall microbial activity (measured as acid phosphatase activity) in a study site in the Southern Appalachian Mountains of North Carolina, but only the effect on microbial activity persisted into the fourth posttreatment growing season. In contrast, in a similar forest in the Central Appalachian Plateau of Ohio, mechanical thinning resulted in increased soil organic C, decreased C:N ratio, and decreased microbial activity, whereas fire and the combination of fire and thinning did not have such effects. In addition, the effects in Ohio had dissipated prior to the fourth posttreatment growing season. Mechanical treatments are attractive in that they require only single entries; however, we see no indication that mechanical-structural restoration actually produced desired belowground changes. A single fire-based/functional treatment also offered little restoration progress, but comparisons with long-term experimental fire studies suggest that repeated entries with prescribed fire at intervals of 3 to 8 years offer potential for sustainable restoration.

10 Bragg, Don C. 2006. **Five years of change in an old-growth pine-hardwood remnant in Ashley County, Arkansas.** Journal of Arkansas Academy of Science. 60. 32–42.

Stand structure and dynamics were evaluated in an old-growth pine-hardwood remnant, the Levi Wilcoxon Demonstration Forest near Hamburg, AR. Some of the pines in this stand exceed 200 years of age and are over 100 cm in diameter and 40 m tall. Over the last 5 years, a significant proportion of the pine overstory succumbed to windstorms, lightning, and beetle attack, especially following a particularly severe storm in May of 2003. The hardwood portions of this forest remained relatively constant, and shade-tolerant hardwoods increased their importance, further suggesting that this pine-dominated stand is gradually becoming a hardwood forest.

11 Bragg, Don C.; Weih, Robert C., Jr. 2007. **Notable environmental features in some historical aerial photographs from Ashley County, AR.** Journal of Arkansas Academy of Sciences. 61. 27–36.

A collection of 1939 aerial photographs from Ashley County, AR, was analyzed for historical environmental features. One noticeable feature in some parts of the county was the coverage of "sand blows," formed by soil liquefaction following strong seismic activity. Also visible in these old photographs are the vestiges of the large prairies once common to this part of Arkansas. Within the grasslands and other areas cleared for farming, numerous "prairie mounds" are also visible across much of the county. Finally, almost 15 000

ha of virgin bottomland hardwoods along the Saline and Ouachita Rivers were noted. Prior to their clearing in the 1940s, these uncut forests may have sheltered the ivory-billed woodpecker.

12 Busse, Matt D.; Beattie, Samuel E.; Powers, Robert F. [and others]. 2006. **Microbial community responses in forest mineral soil to compaction, organic matter removal, and vegetation control.** Canadian Journal of Forest Research. 36(3): 577–588. [Editor's note: Southern Research Station scientists Felipe G. Sanchez and Allan E. Tiarks co-authored this publication.]

We tested three disturbance hypotheses in young conifer plantations: H1—soil compaction and removal of surface organic matter produces sustained changes in microbial community size, activity, and structure in mineral soil; H2—microbial community characteristics in mineral soil are linked to the recovery of plant diversity; and H3—community responses are strongly modified by regional climate. Microbial biomass, respiration, carbon utilization, and phospholipid fatty acids were compared at two subtropical installations and one Mediterranean-type climate installation of the North American Long-Term Soil Productivity Study. Treatments included combinations of compaction (none vs. severe), organic matter removal (none vs. complete), and weed control (none vs. complete), plus an uncut reference stand. Weed control resulted in the only consistent decline or shift in microbial indices at the subtropical sites. At the Mediterranean-type climate site, overstory harvesting resulted in declines in microbial biomass, respiration, and fungal phospholipid fatty acids that far outweighed the effects of the soil disturbance treatments. Severe compaction had no effect on community size or activity at any site. Microbial communities were generally tolerant of postharvest soil disturbance, leading to a rejection of the experimental hypotheses, with the exception of a link between microorganisms and recovery of plant diversity (H2) at the subtropical sites.

13 Coates, T. Adam; Boerner, Ralph E.J.; Waldrop, Thomas A.; Yaussy, Daniel A. 2008. **Soil nitrogen transformations under alternative management strategies in Appalachian forests.** Soil Science Society of America Journal. 72(2): 558–565.

Once subject to frequent fire and strongly nitrogen (N) limited, the forests of the Appalachian Mountains region of Eastern North America have experienced almost a century of fire suppression, and changes in tree species composition, understory density and composition, and accumulations of detritus have paralleled the changes in fire frequency. In an effort to restore these ecosystems and reduce wildfire hazard, alternative management strategies (prescribed fire, mechanical fuel reduction, and a combination of both) were implemented at study sites in Ohio and North Carolina as part of the fire and fire surrogate network study. As changes in N cycling resulting from these treatments could have potential negative impacts on forest health that might limit their usefulness as management alternatives, we monitored treatment effects on extractable total inorganic nitrogen (TIN), net N mineralization, net nitrification, and proportional nitrification during the growing season before treatment, the first growing season after treatment, and the third or fourth-growing season after treatment. Mechanical treatment resulted in increases in extractable TIN, N mineralization, and nitrification during the first posttreatment year in Ohio, and TIN was greater in the mechanical treatment and the mechanical + fire treatment during the third posttreatment year in North Carolina. Net N mineralization was reduced by fire alone in Ohio, but not in North Carolina. Nitrogen transformation rates were two to tenfold higher in Ohio than North Carolina, a difference that may partly result from the ericaceous shrub understory present in North Carolina but not in Ohio. Impacts of these treatments on N transformations were modest and for the most part transient, and would therefore not eliminate these treatments as viable management strategies for wildfire hazard reduction or ecosystem restoration.

14 Connor, Kristina; Schaefer, Gretchen; Donahoo, Jillian [and others]. 2007. **Development, fatty acid composition, and storage of drupes and seeds from the endangered pondberry (*Lindera melissifolia*).** Biological Conservation. 137(4): 489–496. [Editor's note: Southern Research Station scientists Margaret Devall, Emile Gardiner, Tracy Hawkins, Dan Wilson, Nathan Schiff, Paul Hamel, and Theodor Leininger coauthored this publication.]

Pondberry (*Lindera melissifolia*) drupes collected every 30 days after anthesis were examined for seed structure development, fatty acid composition, and storage potential. At 90 days after anthesis, a complete seed had formed within the drupe. Lauric acid increased in quantity as seed matured to become the dominant fatty acid. Oleic acid dominated the fatty acid profile for pulp. Fully hydrated seeds stored well for 16 months at both 4°C and -2°C. Although drying reduced germination when dried seeds were stored at 4°C, seeds dried for 24 hours to a moisture content of 8.6 percent were successfully stored in liquid nitrogen.

15 Fleming, Robert L.; Powers, Robert F.; Foster, Neil W. [and others]. 2006. **Effects of organic matter removal, soil compaction, and vegetation control on 5-year seedling performance: a regional comparison of long-term soil productivity sites.** Canadian Journal of Forest Research. 36(3): 529–550. [Editor's note: Southern Research Station scientists D. Andrew Scott, Kim H. Ludovici, Felipe G. Sanchez, and Allan E. Tiarks coauthored this publication.]

We examined fifth-year seedling response to soil disturbance and vegetation control at 42 experimental locations representing 25 replicated studies within the North American Long-Term Soil Productivity (LTSP) Program. These studies share a common experimental design while encompassing a wide range of climate, site conditions, and forest types. Whole-tree harvest had limited effects on planted seedling performance compared with the effects of stem-only harvest (the control); slight increases in survival were usually offset by decreases in growth. Forest-floor removal improved seedling survival and increased growth in Mediterranean climates, but reduced growth on productive, nutrient-limited, warm–humid sites. Soil compaction with intact forest floors usually benefited conifer survival and growth, regardless of climate or species. Compaction combined with forest-floor removal generally increased survival, had limited effects on individual tree growth, and increased stand growth in Mediterranean climates. Vegetation control benefited seedling growth in all treatments, particularly on more productive sites, but did not affect survival or alter the relative impact of organic matter removal and compaction on growth. Organic matter removal increased aspen coppice densities and, as with compaction, reduced aspen growth.

16 Greenberg, Cathryn H.; Tanner, George W. 2005. **Spatial and temporal ecology of oak toads (*Bufo quercicus*) on a Florida landscape.** Herpetologica. 61(4): 422–434.

We used data from 10 years of continuous, concurrent monitoring of oak toads at eight isolated, ephemeral ponds in Florida longleaf pine-wiregrass uplands to address: (1): Did weather variables affect movement patterns of oak toads? (2) Did pond hydrology and the condition of surrounding uplands affect pond selection by adults or juvenile recruitment? (3) Were population trends evident? and (4) Did a classical metapopulation model best represent their population ecology? Of 4,076 oak toads captured, 92.2 percent were adults. Substantial ($n > 30$ exiting juveniles) recruitment occurred and only three times (once each at three ponds during 2 years). Males outnumbered females (average for all years 2.3:1). Most captures occurred during May to September. Adult captures during June to August increased with heavier rainfall but were not influenced by the durations of preceding dry periods. Movement patterns of metamorphs suggested that oak toads emigrated when moisture conditions became favorable. Pond use by adults correlated with maximum change in pond depth (May to September). Juvenile recruitment was negatively correlated with minimum pond depth and the number of weeks since a pond was last dry, and positively correlated with the maximum number of weeks a pond held water continuously. The number of breeding adults and juvenile recruitment were highest at ponds within the hardwood-invaded upland matrix. The direction of most immigrations and emigrations was nonrandom, but movement occurred from all directions, and the mean direction of pond entry and exit did not always correspond. A total of 21.1 percent of individuals was recaptured; 13.3 percent of first captures were recaptured during the same year, and 7.7 percent during a subsequent year. Only 1.9 percent of captured oak toads moved among ponds, mostly within a distance of 132 m. We did not detect adult population trends over the 10 years studied. Presence or absence at ponds in any given year was a poor indicator of overall use. We saw little evidence of local extinction or "rescue," but were unable to determine whether juveniles returned to natal ponds or colonized new ponds within a landscape to increase the probability of recruitment within the landscape neighborhood during at least some years and at some ponds, and to increase the likelihood of interpond movement.

17 Guldin, James M.; Iffrig, Greg F.; Flader, Susan L., eds. 2008. **Pioneer forest—a half century of sustainable uneven-aged forest management in the Missouri Ozarks.** Gen. Tech. Rep. SRS–108. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 123 p.

This collection of papers analyzes the Pioneer Forest, a privately owned 150,000-acre working forest in the Missouri Ozarks, on which the science and art of forest management has been practiced for more than 50 years. The papers discuss how this half century of management has contributed to forest restoration and sustainability on the forest itself and, through its example undergirded by a remarkable body of research, throughout the Ozark region and beyond.

18 Page-Dumroese, Deborah S.; Jurgensen, Martin F.; Tiarks, Allan E. [and others]. 2006. **Soil physical property changes at the North American Long-Term Soil Productivity study sites: 1 and 5 years after compaction.** Canadian Journal of Forest Research. 36(3): 551–564. [Editor's note: Southern Research Station scientists Felipe G. Sanchez and D. Andrew Scott coauthored this publication.]

The impact of forest management operations on soil physical properties is important to understand, since management can significantly change site productivity by altering root growth potential, water infiltration and soil erosion, and water and nutrient availability. We studied soil bulk density and strength changes as indicators of soil compaction before harvesting and 1 and 5 years after harvest and site treatment on 12 of the North American Long-Term Soil Productivity sites. Severe soil compaction treatments approached root-limiting bulk densities for each soil texture, while moderate compaction levels were between severe and preharvest values. Immediately after harvesting, soil bulk density on the severely compacted plots ranged from 1 percent less than to 58 percent higher than preharvest levels across all sites. Soil compaction increases were noticeable to a depth of 30 cm. After 5 years, bulk density recovery on coarse-textured soils was evident in the surface (0 to 10 cm) soil, but recovery was less in the subsoil (10 to 30 cm depth); fine-textured soils exhibited little recovery. When measured as a percentage, initial bulk density increases were greater on fine-textured soils than on coarser textured soils and were mainly due to higher initial bulk density values in coarse-textured soils. Development of soil monitoring methods applicable to all soil types may not be appropriate, and more site-specific techniques may be needed for soil monitoring after disturbance.

19 Sanchez, Felipe G.; Tiarks, Allan E.; Kranabetter, J. Marty; [and others]. 2006. **Effects of organic matter removal and soil compaction on fifth-year mineral soil carbon and nitrogen contents for sites across the United States and Canada.** Canadian Journal of Forest Research. 36(3): 565–576.

This study describes the main treatment effects of organic matter removal and compaction and a split-plot effect of competition control on mineral soil carbon (C) and nitrogen (N) pools. Treatment effects on soil C and N pools are discussed for 19 sites across 5 locations (British Columbia, northern Rocky Mountains, Pacific Southwest, and Atlantic and Gulf Coasts) that are part of the Long-Term Soil Productivity (LTSP) network and were established over 5 years ago. The sites cover a broad range of soil types, climatic conditions, and tree species. Most sites showed increased soil C and N levels 5 years after study establishment; however, the rate and magnitude of the changes varied between sites. Organic matter removal, compaction, or competition control did not significantly affect soil C and N contents at any site, except for the northern Rocky Mountain site, where competition control significantly affected soil C and N contents. The observation that, after 5 years, the soil C and N contents were not negatively affected by even the extreme treatments demonstrates the high resiliency of the soil, at least in the short term, to forest management perturbations.

20 Scott, D. Andrew; Tiarks, Allan. 2008. **Dual-cropping loblolly pine for biomass energy and conventional wood products.** Southern Journal of Applied Forestry. 32(1): 33–37.

The emerging wood bioenergy market may provide an incentive for landowners to manage their lands for traditional wood products and biomass for energy. We seeded loblolly pine like an agricultural crop between the rows of planted pine trees and remeasured the stand after 22 years. The seeded trees produced 28 tons per acre of wood biomass for energy at age 5, did not reduce planted tree growth even if left unharvested, and did not increase fertilizer requirements. The planted trees developed normally and could be harvested for traditional wood products, while the slash could be harvested for biomass energy.

Forest Values, Uses, and Policies

21 Clark, Alexander, III; Daniels, Richard F.; Jordan, Lewis. 2006. **Juvenile/mature wood transition in loblolly pine as defined by annual ring specific gravity, proportion of latewood, and microfibril angle.** Wood and Fiber Science. 38(2): 292–299.

Intensively managed southern pines grow rapidly during the early years of the rotation, reach merchantable size at a younger age, and thus contain a significantly high proportion of juvenile wood. Juvenile wood is a cylinder of wood surrounding the pith, extending the length of all trees, and is produced by young cambium in the live active crown. Juvenile wood has lower stiffness and strength and more longitudinal shrinkage than mature wood, and thus is not as desirable for lumber production. Landowners and lumber manufactures need to understand the effect of forest management practices on juvenile wood formation. This paper evaluates two methods for determining the year of transition when a tree stops producing juvenile wood and starts to produce mature wood 4.5 feet above ground, based on annual ring specific gravity, proportion of latewood, and microfibril angle.

22 Clark, Alexander, III; Jordan, Lewis; Schimleck, Laurie; Daniels, Richard F. 2008. **Effect of initial planting spacing on wood properties of unthinned loblolly pine at age 21.** Forest Products Journal. 58(10): 78–83.

Young, fast growing, intensively managed plantation loblolly pine (*Pinus taeda* L.) contains a large proportion of juvenile wood that may not have the stiffness required to meet the design requirements for southern pine dimension lumber. An unthinned loblolly pine spacing study

was sampled to determine the effect of initial spacing on wood stiffness, strength, and specific gravity (SG) at 8, 24, and 40 feet up the stem of chipping-saw loblolly pine grown using competition control and fertilization at planting plus fertilization at midrotation. Seven spacings ranging from 6 by 8 feet to 12 by 12 feet were sampled. Analysis of the effect of spacing at each height level showed significant differences in stiffness, strength, and SG among spacings at 8 feet, but did not vary significantly with spacing at 24 or 40 feet. Stiffness at 8 feet of trees planted at 12 by 12 feet was 12 to 14 percent lower than that of trees planted at 6 by 8, 6 by 10, and 6 by 12 feet because the 12 by 12 foot trees were growing rapidly in response to fertilization and less competition, and thus contained a larger diameter of juvenile wood characterized by wide microfibril angles and lower stiffness. Average weighted whole stem wood stiffness and strength decreased only 6 to 7 percent when spacing increased from 6 by 8 feet and 12 by 12 feet, and was not significantly different at the 0.05 level. Estimated stiffness, strength, and SG at 8, 24, and 40 feet decreased significantly with increasing tree height because of increased juvenile wood in the upper stem.

23 Grace, J. McFero, III; Elliot, W.J. 2008. **Determining soil erosion from roads in the Coastal Plain of Alabama.** In: Environmental connection 08, Proceedings of conference 39. Steamboat Springs, CO: International Erosion Control Association: 1–12.

Sediment deposition below forest road sections was measured and modeled in the Coastal Plain on the Conecuh National Forest near Andalusia, AL. Visible sediment deposition zones were tracked along the stormwater flow path to the most remote location as a means of quantifying soil loss from road sections. Volumes of sediment in deposition zones were determined by depth and deposition area measurements. The Water Erosion Prediction Project (WEPP) was used to predict deposition in buffers and sediment leaving buffers from these forest road sections. The study found that of the 16 road segments analyzed, the average road segment length was 45 m (148 feet), and the average quantity of sediment deposited onto the forest floor from road sections was 2.5 tons. The WEPP: road predictions were not significantly different from the observed sediment deposition. This research effort provides information to quantify the magnitude of soil erosion and validate the applicability of WEPP predictions from typical Coastal Plain forest roads in the Southern United States.

24 Grace, Johnny M., III. 2008. **Determining the range of acceptable forest road erosion.** ASABE Pap. 083984. St. Joseph, MI: ASABE: 1–11.

The majority of erosion from forest lands continues to be attributed to forest roads. Previous research over the past 70 years has presented many questions concerning the impact of roads on forest systems. Research has presented some information on the effect of forest road erosion and the benefit of best management practices in controlling erosion. However, one question that needs to be addressed in designing acceptable road systems is, "What is the range of acceptable forest road erosion losses?" This paper presents a summary of forest road erosion losses and their effects on forest systems from various geographical regions considering road design, climatic factors, and management regimes. This paper also provides information to aid in understanding the range of erosion losses that are or have been acceptable based on previous work.

25 Grace, Johnny M., III. 2008. **Influence of storm characteristics on soil erosion and storm runoff.** ASABE Pap. 083979. St. Joseph, MI: ASABE: 1–11.

The volume and sediment concentrations of stormwater runoff emanating from forest roads can be greatly influenced by storm characteristics, road management practices, and/or the interaction of management practices and subsequent storm events. In an attempt to gain a better understanding of storm characteristics on storm runoff, we collected field data from three field experiments in the Appalachian Highlands of northwest Alabama, the Coastal Plain of southeast Alabama, and the Blue Ridge Mountains of northeast Georgia. Storm characteristics explained as much as 40 percent of the variability in runoff concentrations and soil erosion losses from the field experiments. Total precipitation, average rainfall intensity, and maximum 30-minute rainfall intensity were detected as the most influential storm characteristics in determining soil erosion based on the field experimental data from Coastal Plain and Appalachian forest roads.

26 Hwang, Chin-yin; Hse, Chung-yun; Shupe, Todd F. 2008. **Effects of raw materials on the properties of wood fiber-polyethylene composites—part 3: effect of a compatibilizer and wood adhesive on the interfacial adhesion of wood/plastic composites.** Forest Products Journal. 58(5): 66–72.

The objective of this study was to examine the effect of maleated polypropylene compatibilizer on the interfacial properties of wood and polyolefins. Birch wood dowels containing an adhesive applied on the surface were embedded in molten plastic matrices using specially designed jigs. The three plastics investigated included low-density polyethylene (LFPE), linear low-density polyethylene (LLDPE), and polypropylene (PP). The four adhesives used were urea formaldehyde (UF), phenol formaldehyde (PF), isocyanate (ISO), and a control group that did not contain any adhesive. A low-molecular weight emulsion type MAPP, Epolene (E-43) was used at concentrations of

0 (control), 10 percent, 20 percent, 30 percent, and 40 percent. Modified single-fiber pull-out tests were performed to investigate the interrelationships between a four-component system of wood-adhesive-compatibilizer-plastic, simulating the interphase of a wood-thermoplastic composite. The interfacial shear strength as measured by the modified single-fiber pull-out test indicated that the overall average interfacial shear strength was highest in PP and lowest in LDPE. ISO-bonded LDPE without E-43 treatment showed the highest interfacial shear strength among all other LDPE composites. The E-43-treated wood surfaces without adhesive displayed overall superior performance over all adhesive bonded LLDPE. Addition of E-43 greatly enhanced the interfacial shear strength for all plastic types, except for ISO-bonded LDPE and LLDPE. The effect of E-43 was most pronounced in PP and less in LDPE and LLDPE. Adhesive failure prevailed in LDPE and LLDPE composites, while PP showed predominately cohesive failures in the wood dowel or in the plastic matrix.

27 Li, Ruhong; Buongiorno, J.; Turner, J.A.; Prestemon, J. 2008. **Long-term effects of eliminating illegal logging on the world forest industries, trade, and inventory.** Forest Policy and Economics. 10(7-8): 480–490.

We assessed the impact on the world forest sector of a progressive elimination of illegal logging. The analysis compared predictions from 2007 to 2020, with and without a gradual reduction of illegally logged industrial roundwood from 2007 to 2011. A large part of the curtailment of timber supply due to the stoppage of illegal logging would be compensated by increased legal production incited by higher prices. As a result, without illegal logging, the world annual production of industrial roundwood would decrease by no more than 1 percent, even though it would decrease by up to 8 percent in developing countries. World prices would rise by 1.5 to 3.5 percent for industrial roundwood and by 0.5 to 2 percent for processed products, depending on the assumption on illegal logging rates. World consumer expenditures for wood products and producer revenues would rise by 1 to 2 percent without illegal logging. World value added in forest industries would remain the same. However, the changes in consumer expenditures would be more than double the changes in producer revenues in countries dependent on illegally logged timber of domestic or foreign origin such as Indonesia and China. Symmetrically, changes in producer revenues would be almost twice the changes in consumer expenditures in countries with little illegal logging and efficient industries, such as Canada, Germany, and the United States. Value added in forest industries would decrease most in countries with heavy illegal logging (12 percent in Indonesia and up to 9 percent in Brazil), and it would increase most in Germany, Canada (4 percent), and the United States (2 percent). Without illegal logging, the world forest inventory would increase slightly, as the increase in developing countries would more than compensate the decrease in developed countries.

28 Mitchell, Dana; Gallagher, Tom. 2008. **Impacts of extended working hours in logging.** ASABE Pap. 083923. St. Joseph, MI: ASABE: 1–7.

We have researched existing literature to identify possible actions that logging business owners can take to reduce the impact of extended working hours on their employees. Fatigue and mental burnout associated with working long shifts may be reduced by scheduling two or more substantial rest breaks during a shift. Seated exercises or short breaks where operators dismount equipment may relieve the physical impacts of sedentary machine operation. Encouraging employees to try alternative sleep schedules may help workers adjust to late shift working hours. Safety plans should be revised to provide better communication between machine operators during the late shift, and to address additional personal protective equipment for late shift workers. Interviews for hiring new employees should include questions that are structured to find personality traits that may help identify applicants who are more suited for the late shift. Social impacts of permanent late shift assignments may be reduced by offering a flexible schedule where employees can change schedules when needed. Human factors impacts of implementing extended working hours in logging is often overlooked, with the majority of the early planning focused on the financial aspects of implementation. The results of this study may be useful to those considering implementing extended working hours and also to those who have already begun implementation.

29 Mitchell, Dana; Seixas, Fernando; Klepac, John. 2008. **Modified Precision-Husky Progrind H-3045 for chipping biomass.** Forest Operations Review. 10(4). [Not paged].

A specific size of whole tree chip was needed to comill wood chips with coal. The specifications are stringent because chips must be mixed with coal, as opposed to a cofiring process. In cofiring, two raw products are conveyed separately to a boiler. In comilling, such as at Alabama Power's Plant Gadsden, the chip and coal mix must pass through a series of conveyors, a pulverizer, and pipes to the furnace. Handling specifications require smooth cut edges, as opposed to shredded edges. In a partnership involving several entities, including the National Forests in Alabama, Alabama Power Company, Forest-Based Economic Development Services, Precision-Husky, the Forest Service Southern Research Station, and others, a trial was conducted to determine if wood chips could be created in a one-step inwoods process that would meet the

stringent requirements of the power plant. Precision-Husky of Leeds, AL, volunteered to work with the partnership to manufacture a machine that would create the chips to the stringent specifications needed.

30 Prestemon, Jeffrey P.; Donovan, Geoffrey H. 2008. **Forecasting resource-allocation decisions under climate uncertainty: fire suppression with assessment of net benefits of research.** American Journal of Agricultural Economics. 90(4): 1118–1129.

Making input decisions under climate uncertainty often involves two-stage methods that use expensive and opaque transfer functions. This article describes an alternative, single-stage approach to such decisions using forecasting methods. The example shown is for preseason fire suppression resource contracting decisions faced by the Forest Service. Two-stage decision tools have been developed for these decisions, and we compare the expected gains to the agency, in terms of reduced personnel costs, of the single-stage model over the two-stage model, existing hiring decisions, and decisions that would have been made given perfect foresight about wildfire activity. Our analysis demonstrates the potential gains to versions of our single-stage model over existing hiring decisions, equivalent to a benefit-cost ratio of 22. The research also identified additional gains accruing from imposing biases on the single-stage model associated with asymmetric penalties from contracting decisions.

Threats to Forest Health

31 Coulston, John W.; Koch, Frank H.; Smith, William D.; Sapio, Frank J. 2008. **Invasive forest pest surveillance: survey development and reliability.** Canadian Journal of Forest Research. 38(9): 2422–2433.

Worldwide, a large number of potential pest species are introduced to locations outside their native ranges; under the best possible prevention scheme, some are likely to establish one or more localized populations. A comprehensive early detection and rapid-response protocol calls for surveillance to determine if a pest has invaded additional locations outside its original area of introduction. In this manuscript, we adapt and spatially extend a two-stage sampling technique to determine the required sample size to substantiate freedom from an invasive pest with a known level of certainty. The technique, derived from methods for sampling livestock herds for disease presence, accounts for the fact that pest activity may be low at a coarse spatial scale (i.e., among forested landscapes) but high at a fine scale (i.e., within a given forested landscape). We illustrate the utility of the approach by generating a national-scale survey based on a risk map for a hypothetical forest pest species threatening the United States. These techniques provide a repeatable, cost-effective, practical framework for developing broad-scale surveys to substantiate freedom from nonnative invasive forest pests with known statistical power.

32 Coulston, John W.; Riitters, Kurt H.; McRoberts, Ronald E. [and others]. 2006. **True versus perturbed forest inventory plot locations for modeling: a simulation study.** Canadian Journal of Forest Research. 36(3): 801–807. [Editor's note: Southern Research Station scientist William D. Smith coauthored this publication.]

Forest Service Forest Inventory and Analysis plot information is widely used for timber inventories, forest health assessments, and environmental risk analyses. With few exceptions, true plot locations are not revealed; the plot coordinates are manipulated to obscure the location of field plots and thereby preserve plot integrity. The influence of perturbed plot locations on the development and accuracy of statistical models is unknown. We tested the hypothesis that the influence is related to the spatial structure of the data used in the models. For ordinary kriging we examined the difference in mean square error based on true and perturbed plot locations across a range of spatial autocorrelations. We also examined the difference in mean square error for regression models developed with true and perturbed plot locations across a range of spatial autocorrelations and spatial resolutions. Perturbing plot locations did not significantly influence the accuracy of kriging estimates, but in some situations linear regression model development and accuracy were significantly influenced. Unless the independent variable has high spatial autocorrelation, only coarse spatial resolution data should be used to develop linear regression models.

33 Josserand, S.A.; Potter, K.M.; Echt, C.S.; Nelson, C.D. 2008. **Isolation and characterization of microsatellite markers for Carolina hemlock (*Tsuga caroliniana*).** Molecular Ecology Resources. 8(6): 1371–1374.

We describe the isolation and characterization of 31 polymorphic di- and trinucleotide microsatellite marker loci for Carolina hemlock (*Tsuga caroliniana* Englem.). In addition, primer pairs for 16 loci amplified scoreable alleles in 6 other *Tsuga* species. In Eastern North America, both Carolina hemlock and eastern hemlock [*Tsuga canadensis* (L.) Carr.] populations are declining due to infestation by hemlock woolly adelgid (*Adelges tsugae*). The markers described here should enhance population genetic studies of hemlocks, providing valuable information for conserving and restoring these important forest tree species.

34 Linzer, R.E.; Otrosina, W.J.; Gonthier, P. [and others]. 2008. **Inferences on the phylogeography of the fungal pathogen *Heterobasidion annosum*, including evidence of interspecific horizontal genetic transfer and of human-mediated, long-range dispersal.** Molecular Phylogenetics and Evolution. 46(3): 844–862.

Fungi in the basidiomycete species complex *Heterobasidion annosum* are significant root-rot pathogens of conifers throughout the Northern Hemisphere. We utilize a multilocus phylogenetic approach to examine hypotheses regarding the evolution and divergence of two *Heterobasidion* taxa associated with pines: the Eurasian *H. annosum sensu stricto* and the North American *H. annosum* P intersterility group (ISG). Using DNA sequence information from portions of two nuclear and two mitochondrial loci, we infer phylogenetic relationships via parsimony, Bayesian, and median-joining network analysis. Analysis of isolates representative of the entire known geographic range of the two taxa results in monophyletic sister Eurasian and North American lineages, with North America further subdivided into eastern and western clades. Genetically anomalous isolates from the Italian presidential estate of Castelporziano are always part of a North American clade and group with Eastern North America, upholding the hypothesis of recent, anthropogenically mediated dispersal. P ISG isolates from Mexico have phylogenetic affinity with both Eastern and Western North America. Results for an insertion in the mitochondrial rDNA suggest this molecule was obtained from the *Heterobasidion* S ISG, a taxon sympatric with the S ISG in Western North America. These data are compatible with an Eastern Eurasian origin of the species, followed by dispersal of two sister taxa into Western Eurasia and into Eastern North America over a Beringean land bridge, a pattern echoed in the phylogeography of other conifer-associated basidiomycetes.

35 Otrosina, W.J.; Kliejunas, J.T.; Smith, S. [and others]. 2007. **Black stain root disease studies on ponderosa pine—parameters and disturbance treatments affecting infection and mortality.** Acta Silvatica Lignaria Hungarica. Special edition: foliage, shoot, and stem diseases of forest trees: 247–251. [Editor's note: Southern Research Station scientist Shi-Jean Susana Sung and biological science technician Catharine Cook coauthored this publication.]

Black stain root disease of ponderosa pine (*Pinus ponderosa* Doug. Ex Laws.), caused by *Leptographium wageneri* var. *ponderosum* (Harrington & Cobb), is increasing on many eastside Sierra Nevada pine stands in northeastern California. The disease is spread from tree to tree via root contacts and grafts, but overland spread of the disease is most likely due to woody root-feeding bark beetle (*Coleoptera*: *Scolytidae*) vectors. Soil and site relations along with disturbance are factors in the etiology of the disease. Thinning and prescribed burning are important silvicultural tools in maintaining forest health in eastside pine stands. Because soil compaction is a concern in many sites, skid trails are treated by subsoiling equipment to alleviate compaction where this might be an issue. However, little is known of the effects of these silvicultural treatments on incidence of black stain root disease on sites with high disease risk. Because the woody root-feeding insects that vector the disease respond to disturbance, understanding consequences of different disturbances resulting from silvicultural treatments is essential for devising management plans to mitigate disease impact. This paper summarizes preliminary results from two long-term studies initiated in 1996 and 2000 to address these issues.

36 Perry, Roger W.; Thill, Ronald E. 2008. **Diurnal roosts of male evening bats (*Nycticeius humeralis*) in diversely managed pine-hardwood forests.** American Midland Naturalist. 160(2): 374–385.

Forest management affects the quality and availability of roost sites for forest-dwelling bats. However, little is known about roost selection by evening bats (*Nycticeius humeralis*) in the Ouachita Mountains of Arkansas, and roost selection by males specifically has not been studied. Forty-five roosts for male evening bats were located using radio transmitters. Bats roosted in a diverse array of places, including cavities within large live and dead pines (*Pinus echinata*) and small deciduous trees (less than 10 cm in diameter). Sixty-three percent of roosts were in dead trees, 29 percent in live trees, and 8 percent were on or near the ground. One roost was located in tree foliage, one in leaf litter, and one was underground in a small-mammal burrow. All roosts were in forests dominated by large trees (greater than 50 years old), and 71 percent of all roosts were in patches of forest that had not been thinned, possibly because these closed-canopy forests provided cooler sites which allowed more frequent use of torpor during summer. Our results suggest that management intended to provide optimal roosting sites for females may not be applicable to male evening bats.

37 Perry, Roger W.; Thill, Ronald E. 2008. **Roost selection by big brown bats in forests of Arkansas: importance of pine snags and open forest habitats to males.** Southeastern Naturalist. 7(4): 607–618.

Roosts are important to the survival of bats. Although the big brown bat (*Eptesicus fuscus*) is abundant throughout the United States, little is known about roosting behavior in forests of the Southeast, and even less is known about roosting by

males. Thirty-four roosts of big brown bats were located using radiotransmitters in the Ouachita Mountains of Arkansas. All roosts for both sexes were in dead shortleaf pines (*Pinus echinata*), and nearly all roosts were under loose bark. Roosts of males were located in open forests that were less structurally complex than the surrounding forest. Forests where roosts were located had reduced canopy cover, and most areas had been thinned and burned. Although unthinned forests surrounding streams were abundant throughout the study area, big brown bats rarely roosted in those areas. Maintaining a supply of large (greater than 15 cm in diameter) dead pines in relatively open forest habitats, including areas undergoing partial harvest, would provide roosting habitat for male big brown bats in the Ouachita Mountains.

38 Riitters, Kurt H.; Wickham, James D.; Wade, Timothy G. 2009. **An indicator of forest dynamics using a shifting landscape mosaic.** Ecological Indicators. 9(1): 107–117.

The composition of a landscape is a fundamental indicator in landcover pattern assessments. The objective of this paper was to evaluate a landscape composition indicator called "landscape mosaic" as a framework for interpreting landcover dynamics over a 9-year period in a 360,000-km^2 study area in the Southern United States. The indicator classified a land parcel into one of 19 possible landscape mosaic classes according to the proportions of natural, developed, and agriculture landcover types in a surrounding 4.41-ha neighborhood. Using land-cover maps from remote sensing, the landscape mosaics were calculated for each 0.09-ha pixel in the study area in 1996 and 2005. Mosaic transition matrices estimated from the pixel change data were then used to develop two Markov chain models. A "landscape mosaic" model was a temporal model of the shifting landscape mosaic, based on the probability of landscape mosaic change for all pixels. A "forest security" model was the same, except that the Markov states were defined by both the landscape mosaic and the landcover of each pixel, which allowed interpreting forest landcover dynamics in the context of a shifting landscape mosaic. In the forest security model, the overall percentage of forest decreased from 33 percent in 2005 to 17 percent at steady-state, and there was little change in the relative distribution of existing forest area among landscape mosaic classes. In contrast, the landscape mosaic steady-state was reached later, and indicated that a maximum of 10 percent of total area was available for forest. The implication was that forest security depended ultimately on the dynamics of the landscape mosaics that contained forest, not on forest dynamics within those landscape mosaics.

39 Sun, Ge; McNulty, Steven G.; Moore Myers, Jennifer A.; Cohen, Erika C. 2008. **Impacts of multiple stresses on water demand and supply across the Southeastern United States.** Journal of American Water Resources Association. 44(6): 1441–1457.

Predictions from two global circulation models, one land use change model, and one human population model were integrated to project future water supply stress in 2020. We found that population increase greatly stressed water supply in metropolitan areas. Predicted land use and landcover changes will have little effect on water quantity and water supply-water demand relationship. Climate changes had the most pronounced effects on regional water supply and demand. The simulation system developed by this study is useful for water resource planners to address water shortage problems such as those experienced during 2007 in the study region.

40 Sun, G.; Noormets, A.; Chen, J.; McNulty, S.G. 2008. **Evapotranspiration estimates from eddy covariance towers and hydrologic modeling in managed forests in northern Wisconsin, U.S.A.** Agricultural and Forest Meteorology. 148: 257–267.

Direct measurement of ecosystem evapotranspiration (ET) by the eddy covariance method and simulation modeling were employed to quantify the growing season (May to October) (ET) of eight forest ecosystems representing a management gradient in dominant forest types and age classes in the Upper Great Lakes Region from 2002 to 2003. Field data suggested that there were no significant differences in growing season (June to September) ET/precipitation ratio among all ecosystems in 2002. Stand leaf area index alone did not explain ecosystem ET at the landscape scale. Seasonal ET values measured by the eddy covariance method were significantly lower than those simulated with a process-based hydrologic model, MIKE SHE. Our integration approach combined with field measurements and simulation modeling proved to be useful in providing a full picture of the effects of forest cover type change on landscape scale water balance at multiple temporal scales. The ET procedure used in the MIKE SHE model needs improvement to fully account for the effects of vapor pressure deficit on tree transpiration. Seasonal distributions of ET coincided with precipitation in the growing season, when fluxes estimated by both field and models were the highest. The simulation model suggests that removal of conifer forests in the study region may reduce ET immediately by 113 to 30 mm/year or about 20 percent, but our field data suggests that ET can recover within 8 to 25 years from regrowth of hardwood forests.

41 Wickham, James D.; Riitters, Kurt H.; Wade, Timothy G.; Homer, Collin. 2008. **Temporal change in fragmentation of continental U.S. forests.** Landscape Ecology. 23(8): 891–898.

Changes in forest ecosystem function and condition arise from changes in forest fragmentation. Previous studies estimated forest fragmentation for the continental United States. In this study, new temporal landcover data from the National Land Cover Database (NLCD) were used to estimate changes in forest fragmentation at multiple scales for the continental United States. Early and late dates for the landcover change data were ca. 1992 and ca. 2001. Forest density was used as a multiscale index of fragmentation by measuring the proportion of forest in neighborhoods ranging in size from 2.25 to 5314.41 ha. The multiscale forest density maps were classified using thresholds of 40 percent (patch), 60 percent (dominant), and 90 percent (interior) to analyze temporal change of fragmentation. The loss of dominant and interior forest showed distinct scale effects, whereas loss of patch forest was much less scale dependent. Dominant forest loss doubled from the smallest to the largest spatial scale, while interior forest loss increased by approximately 80 percent from the smallest to the second largest spatial scale, then decreased somewhat. At the largest spatial scale, losses of dominant and interior forest were 5 and 10 percent, respectively, of their ca. 1992 amounts. In contrast, patch forest loss increased by only 25 percent from the smallest to largest spatial scale. These results indicate that continental U.S. forests were sensitive to forest loss because of their already fragmented state. Forest loss would have had to occur in an unlikely spatial pattern in order to avoid the proportionately greater impact on dominant and interior forest at larger spatial scales.

Forest Watershed Science

42 Bentrup, G. 2008. **Conservation buffers: design guidelines for buffers, corridors, and greenways.** Gen. Tech. Rep. SRS–109. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 110 p.

Over 80 illustrated design guidelines for conservation buffers are synthesized and developed from a review of over 1,400 research publications. Each guideline describes a specific way that a vegetative buffer can be applied to protect soil, improve air and water quality, enhance fish and wildlife habitat, produce economic products, provide recreation opportunities, or beautify the landscape. These science-based guidelines are presented as easy-to-understand rules-of-thumb for facilitating the planning and designing of conservation buffers in rural and urban landscapes. The online version of the guide includes the reference publication list as well as other buffer design resources: www.bufferguidelines.net.

43 Commens-Carson, Amy M.; Mathis, Alicia. 2007. **Responses of three darter species (genus *Etheostoma*) to chemical alarm cues from conspecifics and congeners.** Copeia. 2007(4): 838–843.

Several species of darters (*Etheostoma*) possess a chemical alarm substance, but it is unknown how widely these compounds occur. Alarm substances are released during predatory attacks when the skin is abraded, causing an anti-predatory response in conspecifics or even other species in the same prey guild. We exposed redfin (*E. whipplei*), fantail (*E. flabellare*), and rainbow (*E. caeruleum*) darters to skin extracts from conspecifics and congeners. Redfin and rainbow darters reacted with a fright response upon exposure to skin extracts from conspecifics and each other. Neither rainbow nor redfin darters responded to fantail skin extract. Fantail darters did not respond to skin extracts from congeners or conspecifics. We demonstrated that chemical alarm signals are not ubiquitous for the genus *Etheostoma*.

44 Coyle, D.R.; Coleman, M.D.; Durant, J.A.; Newman, L.A. 2006. **Multiple factors affect pest and pathogen damage on 31 *Populus* clones in South Carolina.** Biomass & Bioenergy. 30(8–9): 759–768.

Populus species and hybrids have many practical applications, but there is a paucity of data regarding selections that perform well in the Southeastern United States. We compared pest susceptibility of 31 *Populus* clones over 3 years in South Carolina, USA. Cuttings were planted in spring 2001 on two study sites. Clones planted in the bottomland site received granular fertilizer yearly and irrigation the first 2 years only, while those on the sandy, upland site received irrigation and fertilization throughout each growing season. Foliar damage by the cottonwood leaf beetle (*Chrysomela scripta*), cottonwood leafcurl mite (*Tetra lobulifera*), and poplar leaf rust (*Melampsora medusae*) was visually monitored several times each growing season. Damage ratings differed significantly among clones, and clonal rankings changed from year to year. Irrigation increased *C. scripta* and *M. medusae* damage, but had no effect on *T. lobulifera* damage. Certain clones received greater pest damage at a particular study site. Temporal damage patterns were evident among individual clones and on each site. Based on this preliminary 3-year study of pest damage levels, we would recommend clones NM6, Eridano, I45/51, OP367, 15–29, 7302801, 7300502, and Kentucky 8 for use in this region.

45 Dosskey, M.G.; Helmers, M.J.; Eisenhauer, D.E. 2008. **A design aid for determining width of filter strips.** Journal of Soil and Water Conservation. 63(4): 232–241.

Strategies for water-quality improvement in developed landscapes often include vegetated filter strips. Wider strips work better for stabilizing soil and promoting runoff infiltration and sediment deposition, but widening beyond what is necessary can add to costs and create resistance to adoption by landowners. This graphical design aid, developed from simulations using a process-based mathematical model, is accurate enough for developing cost-effective site designs and easy enough to use for making quick determinations on a large number and variety of sites. By quantitatively relating width to level of performance, this tool will enable watershed planners to develop appropriate designs where specific water-quality targets must be met.

46 Gardiner, Emile; Stanturf, John; Leininger, Theodor [and others]. 2008. **Establishing a research and demonstration area initiated by managers: the Sharkey Restoration Research and Demonstration site.** Journal of Forestry. 106(7): 363–369.

This article documents our experience with establishment of a forest restoration research and demonstration area in the Lower Mississippi Alluvial Valley (LMAV), a region experiencing extensive afforestation. Although basic plantation establishment techniques had been developed and applied on small areas, managers lacked critical knowledge to implement operational-scale practices. This 1,700-acre research and demonstration area has provided a science-based resource for educating landowners, managers, and the general public; has served as a platform for scientists and managers to cooperate on development of innovative forest restoration approaches; and has provided a venue for debate among policymakers actively promoting forest restoration in the LMAV.

47 Hawkins, Tracy S.; Baskin, Jerry M.; Baskin, Carol C. 2007. **Seed morphology, germination phenology, and capacity to form a seed bank in six herbaceous layer *Apiaceae* species of the eastern deciduous forest.** Castanea. 72(1): 8–14.

We compared seed mass, seed morphology, and long-term germination phenology of three monocarpic (M) and three polycarpic *Apiaceae* species. Seeds of the six species differed considerably in mass, shape, and ornamentation. Mean seed masses were ranked *Cryptotaenia canadensis* (M) < *Thaspium barbinode* (P) < *Sanicula canadensis* (M) < *S. gregaria* (P) < *Osmorhiza claytonii* (P) < *S. trifoliata* (M). Germination peaks occurred in the first or second spring following sowing. Germination of some seeds was delayed until the sixth year. Potential to form a (modified) type III or (modified) type IV persistent soil seed bank was not related to seed mass, shape, or ornamentation. Germination peak was related to time of dispersal and type of seed dormancy.

48 Lockhart, Brian Roy; Gardiner, Emile; Leininger, Theodor; Stanturf, John. 2008. **A stand-development approach to oak afforestation in the Lower Mississippi Alluvial Valley.** Southern Journal of Applied Forestry. 32(3): 120–129.

Oak (*Quercus* spp.) afforestation in the Lower Mississippi Alluvial Valley has involved planting 1-year-old bareroot seedlings on a relatively wide spacing in single-species stands or planting light-seeded species with oaks to form mixed-species stands. In the former case, the developing single-species stands have limited future management options because they do not provide structures that favor quality wildlife habitat or quality sawtimber production. In the latter case, species mixtures are being planted with little knowledge of subsequent stand development, leading to an inability to predict future stand composition for management purposes. In this article, we present a system to determine bottomland tree planting mixtures that will create single-cohort, mixed-species stands with a component of high-quality bottomland oak. Using individual species ecological life-history characteristics, such as early height growth pattern, relative twig diameter and durability, and developmental patterns in natural stands, bottomland species are rated for their ability to provide beneficial training effects that will lead to the development of quality oak boles. Incorporating such a system to determine species value in mixtures should provide an increased number of future options to meet explicit management objectives and promote improved restoration of bottomland hardwood ecosystems.

49 Meier, Calvin E.; Stanturf, John A.; Gardiner, Emile S. 2006. **Litterfall in the hardwood forest of a minor alluvial floodplain.** Forest Ecology and Management. 234: 60–77.

Within mature deciduous forests, annual development of foliar biomass is a major component of aboveground net primary production and nutrient demand. As litterfall, this same foliage becomes a dominant annual transfer of biomass and nutrients to the detritus pathway. We report litterfall transfers of a mature bottomland hardwood forest in a minor alluvial floodplain within the middle Coastal Plain physiographic province of central Louisiana, USA. Climate is humid subtropical. Floodplain forests of minor alluvial streams may account for nearly half the remaining acreage of bottomland forests in the Southeastern USA and differ markedly from those of major alluvial rivers and deep-water swamps. For a 3-year period, litterfall magnitude, components, leaf species, and timing were monitored by monthly collection

of materials from litterfall collectors. Variations in litterfall transfers across 10 study plots and their relationships to forest parameters are evaluated. Mean transfers of total litterfall, leaf fall, reproductive structures, fine wood, and other litterfall were 816, 512, 130, 98, and 76 g m^{-2} $year^{-1}$, respectively. *Quercus pagoda* Raf., *Q. nigra* L., and *Liquidambar styraciflua* L. accounted for an average of 49 percent of annual leaf fall, with 11 tree species and canopy vines accounting for 94 percent of total annual leaf fall. A total of 38 species and genera contributed to total leaf fall. Variation in total litterfall and leaf fall transfers across the alluvial bottom were related to size of overstory trees and their species composition. Higher and more consistent mass transfers of reproductive structures were observed than previously reported for upland hardwood stands.

50 Nelson, John L.; Groninger, John W.; Battaglia, Loretta L.; Ruffner, Charles M. 2008. **Bottomland hardwood forest recovery following tornado disturbance and salvage logging.** Forest Ecology and Management. 256(3): 388–395.

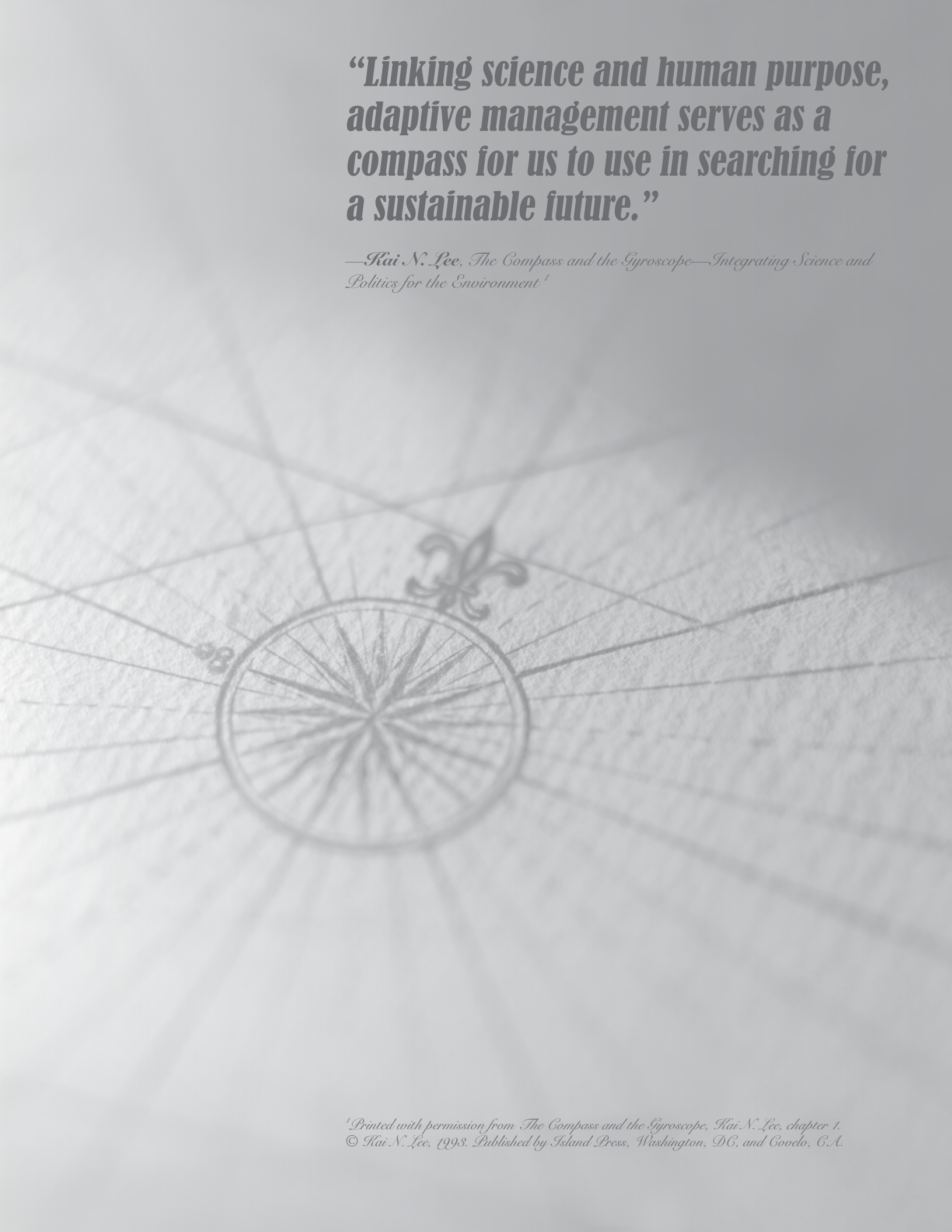
This research examines bottomland hardwood forest recovery following differing levels of canopy and soil disturbance following a tornado and subsequent salvage harvesting. Forest recovery was rapid for all disturbance types and intensities, with composition of developing stands related to disturbance intensity. Vegetation diversity was greatest on the most highly disturbed plots. Salvage harvesting restored micro-topography that had been eliminated by decades of agricultural land use prior to establishment of the previous stand. This study increased our understanding of bottomland hardwood forest development and demonstrated that salvage harvesting can be used to promote desirable forest conditions in a conservation management setting.

Research Work Units

Location and project leader	Name and 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		
Gainesville, FL Vacant	Integrating Human and Natural Systems www.srs.fs.usda.gov/trends	352-376-3213
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. forestthreats.org	828-257-4854
Athens, GA John Stanturf	Center for Forest Disturbance Science www.srs.fs.usda.gov/disturbance	706-559-4316
Pineville, LA Vacant	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*[1]



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Canoeing on the Ouachita River in Arkansas. (Forest Service photo by Bill Lea)