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

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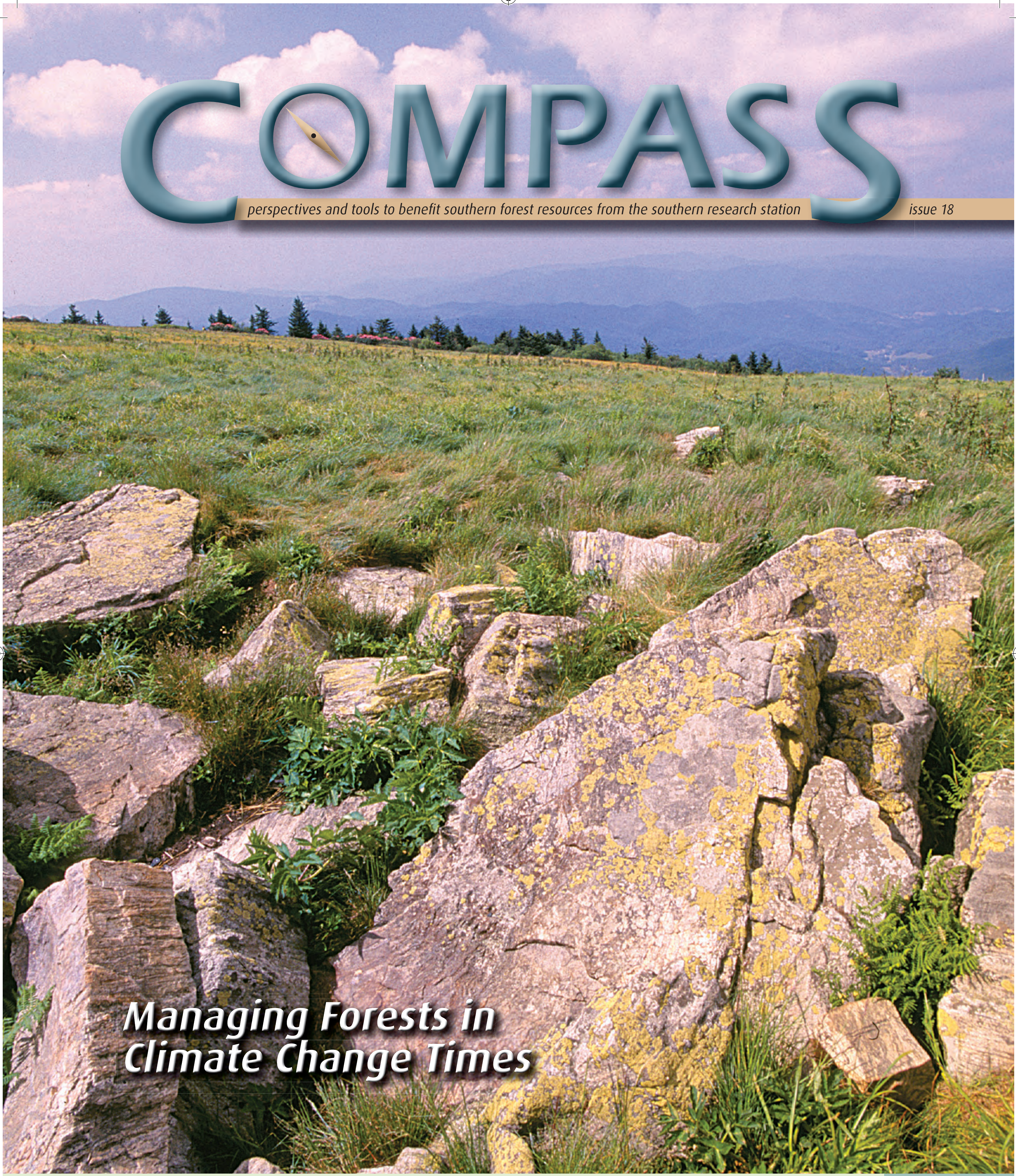

Managing Forests in Climate Change Times

inside...
the science

On the cover: Rising temperatures are of particular concern for mountain islands such as Roan Mountain in northeast Tennessee, where the cold harsh climate shelters some of the rarest plant and animal communities in the world. (photo by USDA Forest Service)

Chief among the benefits provided by southern forests is clean water. (photo by USDA Forest Service)

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COMPASS

Science You Can Use!

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perspectives and tools to benefit southern forest resources

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

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Climate Change, Forests, and Water

Americans rely on their forests and grasslands for a wide range of benefits. Chief among these is clean water. Over 180 million people depend on forested watersheds for their drinking water. Watershed protection was one of the primary reasons for the founding of the Forest Service more than a century ago, a time when America had lost about 200 million acres of forest due to land clearing for agriculture and timber. Because of the loss of forested watersheds, the water in many U.S. streams and rivers was too polluted to drink. Today the 155 national forests and grasslands cover over 193 million acres in 43 states and Puerto Rico, with a core purpose of assuring plentiful supplies of clean water to the American people.

In an era of climate change, forests will play an increasingly vital role in protecting the Nation's watersheds.

Photo by José Manuel Suárez, courtesy of Wikimedia Commons

Managing Forests in Climate Change Times

Science Provides New Tools

Land managers in the South are very aware that the forests under their care—and the benefits those forests provide—are at risk due to the effects of climate change.

Forests are vital to our region for the range of benefits they provide. They clean water, ensuring quality drinking water supplies to millions. They purify the air we breathe. They store carbon and regulate climate. They form soils and control runoff and erosion and provide habitat for a wide range of wildlife. All of these services are connected and sustained through the integrity of the ecosystems on these lands. Climate change places those ecosystems at risk.

Over the last two decades, some of the most urgent challenges for land managers—wildfires, drought and floods, expanding insect infestations, nonnative plant invasions—have been driven in part or enhanced by changing climate patterns. Future impacts are projected to be even more severe.

Forests in the South are already showing the effects of climate change.

The fire season is starting earlier and ending later. In the Southern Appalachian region, warmer winter temperatures have accelerated the extirpation of Eastern hemlock trees by a nonnative insect, the hemlock woolly adelgid. Even for native insects such as the southern pine beetle, infestations are larger and longer, killing more trees and increasing fire risk. Warmer temperatures are allowing cold-intolerant nonnative invasive plants to move farther north into vulnerable forests.

Forests reduce erosion, regulate stream flows, and provide habitat for wildlife. (photo by USDA Forest Service)

If warming continues as anticipated, the number and severity of large wildfires and insect and nonnative invasive plant infestations will more than likely increase even further. Meanwhile, the frequency of hurricanes and storms will also increase. Storm damage reduces the ability of forests to store carbon and to provide the clear, clean water we've come to depend on.

Managing for Yet More Disturbance

The good news is that the Forest Service has always been about managing for disturbance. Forest Service research has, since its beginning, provided the knowledge needed to grow new forests, restore degraded watersheds, and sustain habitat while providing Americans with jobs, recreational opportunities, and aesthetic beauty.

The Southern Research Station (SRS) is uniquely poised to help the South's forest managers plan for the impacts of climate change. Almost a century of SRS science has produced a wealth of silvicultural studies, long-term data, and expertise in modeling the effects of disturbances that range from wildfire to insects to climate change. The science that served to reforest a South almost completely cutover at the beginning of the 20th century stands ready to provide practical applications to forest managers anticipating climate change.

In this issue of *Compass*, we'll look at programs designed to help national forests implement the Forest Service *National Roadmap for Responding to Climate Change* released this February, predict water availability in relation to climate change, and project the likelihood of wildfire. We'll also see how new collaborations between Federal agencies are working to ensure habitat for coldwater trout and other aquatic species and provide new information to help support the restoration of longleaf pine forests.

Answering the Call

Making Science Accessible for Forest Planners

by Emrys Treasure

The phone rang.

In the age of email, video conferencing, Twitter and blogs, it's a sound **Steve McNulty**, senior research ecologist and leader of the **Eastern Forest Environmental Threat Assessment Center** (EFETAC) team in Raleigh, NC, hears less and less often.

"Don't get me wrong," says McNulty. "Calls do still come in occasionally from folks like a professor in New England, a scientist out of the Rocky Mountain Station, or a technician from the local soils lab. But this call was different. This call was from a forester, and he wanted answers."

McNulty's been studying climate change impacts on forests for the past 20 years. During this time, he's cranked out over 150 papers, given hundreds of lectures, and participated in more assessments and strategy documents than he can recall. All of these activities had one thing in common: scientists talking to scientists. Since McNulty started with the Forest Service in 1991, "there two things you could count on. First, the climate was getting steadily warmer, and second, only scientists seemed to care."

"So imagine my surprise when a forester wanted to find out if all this talk about climate change was real and if it were real, what should he be doing about it," says McNulty. "After waiting two decades for someone outside the science ranks to ask me about

Tupelo-baldcypress swamp in the DeSoto National Forest in southern Mississippi. (photo by USDA Forest Service) climate change, I was embarrassingly unprepared to provide an answer."

"It wasn't that I didn't understand climate change or what types of ecosystem impacts could occur," he adds. "The problem was that I had not been talking with land managers, and did not know how to translate science speak into management actions."

That was 5 years ago. Meanwhile the whisper about climate change turned into a low rumble and now is more like a roar. With 2010 cited by some as the warmest year in recorded history—people are starting to understand that the climate is indeed changing.

In forests, climate change ramps up the stress already occurring from extreme weather events, disease and insect outbreaks, catastrophic wildfires, and invasive species. Resilient forests are better able to absorb stress without compromising the services they afford. In the same way that good sleep, healthy diet, and regular exercise make a person resilient (though not immune) to illness, forests can be helped towards resiliency by management practices that focus on sustaining or restoring ecological integrity in relation to future conditions. While neither the many threats to forests nor the management approaches available to abate them are new to forest managers, climate change introduces additional pressure and the need for the rapid translation of emerging science into forest management practice.

In early 2009, a group of researchers led by McNulty partnered directly with forest planners from across the **Southern Region** of the **National Forest System** (Southern Region) to start looking at what needed to be done to address the looming problems posed by climate change. A series of meetings were held to share information and ideas about solutions. The results of this collaboration are captured in the **Template for Assessing Climate Change Impacts and Management Options** (TACCIMO), a Web-based technology designed specifically for natural resource management under climate change.

It's come at just the right time. "There's a pressing need to develop science-based tools to assist land managers in decisionmaking and planning around not only climate change, but also in relation to the dramatic demographic, land use, and resource demand changes also taking place today," says McNulty.

It All Starts with Planning

For forest planners, that "roar" around climate change is about to turn into a deafening din. The proposed Forest Planning Rule released in February 2011 mentions "climate change" 23 times. The Planning Rule, required under the National Forest Management Act of 1976, guides the process the national forests use to develop long- and near-term management plans and mandates the use of best available science and input from the public to guide forest direction.

"Planning is the hub of the resource stewardship wheel," says **David Meriwether**, acting director of planning for the Southern Region, "but the rubber meets the road when we start taking actions." Meriwether goes on to say that "never in my 30-year plus career has the sustainability of forests been threatened by so many simultaneous problems. Our actions need to be guided by even better informed plans."

The current and historic problems that Meriwether refers to include threats to forests from invasive species, forest fragmentation, insects

(continued on page 4)

The Roadmap and the Scorecard

To implement the goals outlined in the 2010 USDA Strategic Plan for 2010-2015, the Forest Service released the ***National Roadmap for Responding to Climate Change*** in July 2010. The roadmap focuses on the strategic plan goal to "ensure our national forests and private working lands are conserved, restored, and made more resilient to climate change, while enhancing our water resources." The Forest Service implemented a **Performance Scorecard** to measure the progress made by local national forest and grassland units—with support from regional offices, research stations, and national programs—towards this goal.

The scorecard tracks progress in four dimensions—agency or organizational capacity, engagement, adaptation, and mitigation—through a set of 10 questions. The questions are designed to be flexible enough to be addressed through a range of approaches and at different geographic scales. Scorecard assessments began in spring 2011, with a goal of 100 percent of all national forests and grasslands in compliance by 2015.

To download or read the roadmap: www.fs.fed.us/climatechange/pdf/roadmapfinal.pdf

To view the scorecard: www.fs.fed.us/climatechange/pdf/Scorecard.pdf

Answering the Call

(continued from page 3)

and disease, loss of imperiled species, and the devastating effects of wildfire.

"National forest planning teams are already trying to address very complex management situations," says **Paul Arndt**, regional planner for the Southern Region. When they factor in climate change, the implications of which can be so far reaching, it's hard to know where to begin."

Answering the Call

TACCIMO engages climate change challenges to forest stewardship head on. Developed jointly through a partnership between EFETAC and the Southern Region, TACCIMO pulls together in one place the science-based information managers need to plan across multiple forests and scales.

TACCIMO leads forest managers through the thought process of assessing what climate change may mean for their specific forests. Based on emerging needs and discussion between scientists and managers, TACCIMO is constantly updated with searchable quotations from peer-reviewed scientific literature that describe impacts and management options. To make the connection between science and management literal, forest plans for all of the national forests east of the Mississippi are provided in TACCIMO as an organized resource. A custom map viewer enables exploration of climate change projections across selected regions.

Before TACCIMO, there was no central resource for national forest planners and managers to turn to. Even more important than putting the information all in one place, TACCIMO provides a visual interface where multiple types of information can be connected or layered with existing forest plans. Forest managers can see what the potential impacts are in a given area, what management options exist, and which aspects of their existing plan might be affected. The TACCIMO experience is captured in exportable science reports that document climate change impacts on forest planning and management, while spatial variability and projected range of future climate are presented in geospatial reports.

Ken Landgraf, planner for the **George Washington National Forest** (GWNF), is well along in the process of revising the plan for the GWNF. "The public has been very interested in how climate change may affect our forest and they want us to consider these potential effects as we develop management direction,"

A team of researchers from the Forest Service Eastern Forest Threat Assessment Center (EFETAC) and the Southern Region received the 2010 Regional Forester Award for Technology Transfer for their work on TACCIMO. (left to right) Steve McNulty and Emrys Treasure from EFETAC; David Meriwether, Paul Arndt, Chris Liggett, and Jerome Thomas from the Forest Service Southern Region. (photo by USDA Forest Service)

Template for Assessing Climate Change Impacts and Management Options (TACCIMO)

TACCIMO is a Web-based assessment and reporting tool that makes the connection between climate change science and forest planning information. A collaborative effort between **Eastern Forest Environmental Threat Assessment Center researchers** and **National Forest System Southern Region** planners and land managers—TACCIMO uses a database of climate change forecasts, direct ecosystem impacts, and management options to generate customized reports that aid with forest planning and management. Users can choose issues of interest such as biodiversity, forest pests, forest land conversion, prescribed fire, recreation, and wildfire. Based on user-defined selections, TACCIMO links direct and indirect effects of climate change with possible management options for lessening climate change impacts in targeted U.S. geographic regions. TACCIMO also allows users to explore future climate projections through an integrated mapping tool.

TACCIMO delivers current, relevant information to a range of users, including Federal and state agencies, nongovernmental organizations, and private landowners. For Federal land managers and Forest Service planners in particular, TACCIMO helps deliver the best available science which fits within the National Environmental Policy Act process.

TACCIMO databases and literature are continually updated and expanded as new knowledge and science emerge and information needs change.

TACCIMO includes resources for training and assistance. In addition to a detailed user guide, TACCIMO provides case studies and quick-start guides with basic instructions for navigating the tools and resources, generating reports, and using its mapping tools.

For more information:
www.forestthreats.org/tools/taccimo

says Landgraf. "While we understand their concerns, responding to an issue as broad as climate change in the analysis for a forest plan revision has been challenging. TACCIMO provided a lot of information for us to use in responding to the issue. The geospatial report allowed us to scale down potential changes in temperature and precipitation to the GWNF, while the science report allowed us to pull together information on effects that are relevant to our area. Both of these sets of information were a great help in preparing the environmental effects section of the required Environmental Impact Statement."

The Future is Here

In addition to the proposed Planning Rule, the ***National Roadmap for Responding to Climate Change*** and a supporting ***Scorecard*** that tracks implementation are driving action on national forests. No longer will the demand for climate change science be limited to those planning for 30 or more years down the road. TACCIMO and the community of researchers and land managers it represents are ready to tackle climate change with 21st-century science and tools. At the end of the day, TACCIMO is about the people behind it—scientists, planners, forest managers, and ultimately, the American public.

Bringing researchers and forest managers together to address problems is nothing new, but the technology stands to make the process more responsive and efficient than ever before. What TACCIMO captures for all to benefit from is the experience of a forest manager picking up the phone and asking a scientist what he or she can do to ready our forests for climate change.

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Recommended reading:

Blate, G.M.; Joyce, L.A.; Littell, J.S. [and others]. 2009. **Adapting to climate change in United States national forests.** Unasylva. 60(231/232): 57–62.

Emrys Treasure is a biological scientist and the TACCIMO coordinator based at the Eastern Forest Environmental Threat Assessment Center in Raleigh, NC.

Cold water for trout

Joint research by SRS and the U.S. Geological Survey

by Zoë Hoyle

The names of southern rivers—Roanoke, French Broad, Neuse, Apalachicola, Tar, Tennessee—are nothing if not evocative. As you read them, you may think first of the long human history of the area, but the rivers and streams of the Southeastern United States are actually better known worldwide for the unique and diverse aquatic ecosystems they harbor.

The Southeast is also an area of rapidly expanding human population and increasing demands for sources of clean drinking water, and in the hot summers, for places to swim, fish, and boat. During severe summer droughts, human demands for water have already come into direct conflict with the habitat needs of aquatic species, pitting state against state, and states against Federal agencies.

Species in these ecosystems—fish, mussels, crayfish, salamanders, especially those dependent on cold temperatures such as native eastern brook trout—are already stressed by recurring droughts and will undoubtedly be impacted further by climate change.

Resource managers in the Southeast are more and more challenged to balance human demands for water quantity and quality with the habitat needs of freshwater aquatic species. Managers have access to national databases and models from multiple sources, but lack both regional data and a framework for addressing species and site-specific questions. To develop strategies and to make decisions designed to minimize the effects of climate change on both humans and aquatic species, managers need more precise science-based tools.

In 2010, the Forest Service and the **U.S. Geological Survey** (USGS) joined forces in a multiyear project to refine and combine climate and hydrologic models to provide a better understanding of climate effects on freshwater fish and water quality and quantity in the region.

In the Mountains, Cold Water for Trout

The Southeastern United States is home to many aquatic habitats, ranging from the high-elevation coldwater streams of the Appalachian Mountains to the low-elevation warmwater streams of the Coastal Plains. In the mountains, rising water temperatures may restrict native brook trout to higher elevations; under the most pessimistic climate change scenarios brook trout could largely disappear from their native ranges except in isolated high mountain refuges.

Rising temperatures may restrict native eastern brook trout to higher elevation coldwater refuges. (drawing by Duane Raver, U.S. Fish and Wildlife Service, courtesy of Wikimedia Commons)

SRS scientist **Andrew Dolloff** leads the Forest Service side of the Forest Service-USGS collaboration in a project that's based on a larger study Dolloff has been working on with biologists from the National Forest System on the relationship between air and water temperature in mountain watersheds that support coldwater species such as brook trout. This study involves installing paired air and water thermographs (digital thermometers) at the downstream-most point of selected brook trout patches in an area that extends northsouth from Maine to Georgia.

Data from a pilot study in Virginia yielded some interesting results.

"Previous large-scale assessments of the effects of climate change on coldwater fish species used models that assume that the correspondence between air and water temperature stays pretty constant, at about 0.8 to 1.0 degrees," says Dolloff. "At the habitat patch scale, which corresponds to where trout actually live, we've found that this correspondence varies in relation to elevation, aspect, riparian cover, and other local conditions."

With 250 watersheds in the Southern Appalachians instrumented and several hundred more sites established in the northeastern states, this project will provide managers with direct and precise information they can use to plan future habitat for brook trout across the East.

"We plan to use the relationship of air and water temperature along with knowledge of trout distribution and abundance across a variety of habitats to identify and rank the resiliency of southern mountain watersheds to climate change," says Dolloff.

SRS research on the relationship between air and water temperature and other conditions will help managers identify coldwater habitats that will be resilient under climate change. (photo by USDA Forest Service)

"This will give managers another tool to help prioritize locations to ensure the survival of brook trout and other coldwater species."

Transitions from Cold to Warm

For the USGS collaboration, Dolloff and partners are expanding their study into the very different environments of the Piedmont and the Coastal Plain, where a network of rivers and streams feed into the Albemarle-Pamlico Sound along the coasts of Virginia and North Carolina.

While the core data collections in the expanded study also emphasize temperature and landscape habitat attributes, the emphasis for this part of the project is more on the possible impacts of rising temperatures on relationships among temperature, water quality, aquatic communities, and ecosystem services to meet human demands.

"We don't know yet if the relationships we found in coldwater streams can be extrapolated to cool or warmwater streams," says Dolloff. "We'll collect data from paired thermographs located from the mountains down to the Coastal Plain. Then we'll overlay that data with USGS data from the area to see if we can develop a similar means to identify habitats that will be particularly resilient under climate change."

Scientists from both agencies will assess specific stream conditions needed to support key fish species that rely on cold water and model the likelihood of the occurrence of those species in any given stream patch. With combined models, the project will define cold- and warmwater stream areas, homing in on the transitions from cold to warm water, and the resulting effects on fish communities. To test a range of climate change scenarios from 2000 to 2100, climate change projections will be integrated with the new combined stream models.

"The ultimate goal of this collaborative modeling effort is to provide tools managers and planners can use to look at how well different strategies will work under climate change and in relation to projected land use patterns," says Dolloff.

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Trees in Transition

by Stephanie Worley Firley

In forests as in life, the only constant is change. Forest species are ever adjusting to changing conditions resulting from seasonal fluctuations in temperature and precipitation, disturbances such as storms and wildfire, and interactions with other species. But typical temperature and precipitation patterns are now also changing; in some areas, climatic changes are occurring rather rapidly, which could pose a severe threat to forest trees. Whether tree populations adapt onsite to changing habitat conditions, shift their ranges to new suitable locations, or simply die out, the forests we know today—and the genetic makeup of the species within them—could be very different by the middle of the 21st century.

Kevin Potter collects cones from a Fraser fir tree on Mount Rogers in Virginia. As a high-elevation species, Fraser fir may be at particular risk from climate change. (photo courtesy of Kevin Potter, North Carolina State University)

Now researchers from the **Eastern Forest Environmental Threat Assessment Center** (EFETAC) are asking the question: In a future with a different climate, where might the trees be?

With support from the Forest Service **Forest Health Monitoring Program**, EFETAC ecologist **Bill Hargrove** and **North Carolina State University** cooperating scientists **Kevin Potter** and **Frank Koch** are collaborating to develop **Forecasts of Climate-Associated Shifts in Tree Species** (ForeCASTS). Using projections of future climate in combination with the concept of fine-scale ecoregions—land areas that share similar environmental characteristics such as soils, topography, and climate variables—the researchers are developing maps depicting future suitable habitat ranges for tree species within the United States as well as across the globe.

ForeCASTS maps can help scientists, land managers, and policymakers target tree species for monitoring and management activities by pinpointing locations where climate change pressures are likely to be most intense.

"The Forest Service has a long history of understanding that the seed source makes a huge difference in tree growth and performance," says Hargrove. "ForeCASTS maps can ultimately be used to assess the risk to genetic integrity of North American forest tree populations."

Parts of the current range of longleaf pine may become less suitable for the species as climate changes. (photo courtesy of Kevin Potter, North Carolina State University)

Potter adds, "The ForeCASTS project can help guide decisions about how and where to invest time and funds for conservation efforts." Conserving genetic variation is particularly important because it confers the evolutionary potential to adapt to change, reducing susceptibility to stressors like insects and pathogens in addition to climate change.

So far, the researchers have developed maps for 213 tree species under varying climate models and scenarios for the years 2050 and 2100, including "minimum required movement" maps that quantify the distances between existing habitat that may become unsuitable in the future and the nearest future suitable habitat. "The general trend, as we would expect, is for tree ranges to expand at least a little bit to the north, and to drop off at least a little bit at their southern edges," says Potter. "Looking at species with ranges that include the Southern Appalachians, the ForeCASTS maps show nearly all species decreasing their overall suitable habitat area."

The ForeCASTS maps are still provisional. As the project unfolds, the researchers are refining the available map products and adding additional species to the queue. They plan to identify closest "lifeboat" areas for tree species that may migrate from multiple locations as well as add measures of performance to determine where species may thrive in future projected habitat ranges. Later, the methods used in ForeCASTS could be employed to explore future distributions of invasive species to aid in proactive management of vulnerable forest ecosystems.

ForeCASTS:

www.forestthreats.org/tools/ForeCASTS

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Recommended reading:

Potter, K.M.; Hargrove, W.W.; Koch, F.H. 2010. **Predicting climate change extirpation risk for central and Southern Appalachian forest tree species.** In: Rentch, J.S.; Schuler, T.M., eds. Proceedings from the conference on ecology and management of high-elevation forests of the central and Southern Appalachian Mountains. Gen. Tech. Rep. NRS–P–64. Newtown Square, PA: U.S. Department of Agriculture Forest Service, Northern Research Station: 179–189.

Stephanie Worley Firley is a biological science information specialist with EFETAC in Asheville, NC.

FOLLOWING CARBON'S TRAIL

by Sarah Farmer

Carbon, the chemical foundation of life, cycles through forests, seas and skies, and at some stages is stored or sequestered, from the atmosphere. Trees are one such storage vault.

The **U.S. Department of Defense** (DOD) hopes to use the longleaf pine forests on their lands to sequester carbon while protecting biodiversity and restoring ecosystems. Funded by DOD, SRS plant physiologist **Kurt Johnsen** and his **Forest Genetics and Ecosystems and Biology** team are working with university researchers to measure the carbon stored in longleaf pine ecosystems and construct a model that shows how carbon moves through young stands (0 to 50 years old) and older stands (40 to over 200 years old). DOD will use the model to evaluate different forest management strategies on three military bases in the South where they manage and restore longleaf pine forests.

Lisa Samuelson, director of the **Center for Longleaf Pine Ecosystems** at Auburn University, will direct the overall project and lead efforts to measure carbon in aboveground and taproot biomass. **Tim Martin**, director of the **Carbon Resources Science Center** at the University of Florida, and his team will combine data from the research project and other literature to develop the carbon model and management tools. Johnsen and his team will study belowground carbon to understand how it moves from living roots to soils, and measure coarse root biomass and the decomposition rates of taproots.

To examine belowground carbon, Johnsen's team will use the ground-penetrating radar (GPR) techniques they've developed for measuring tree

SRS researchers excavate whole root systems to measure carbon and validate findings from the ground penetrating radar (GPR) methods they've developed. (photo by USDA Forest Service)

With funding from the U.S. Department of Defense, SRS researchers and university collaborators are developing a model to show how carbon moves through longleaf pine stands of different ages. (photo by USDA Forest Service)

root biomass. GPR is a nondestructive tool that lets researchers peer belowground at roots, which can account for 15 to 45 percent of pine stand biomass. Along with using GPR, Johnsen and his crew will excavate whole root systems that have been dead for known periods of time to measure the remaining carbon. "By comparing these quantities to carbon present in living root systems, we can determine decomposition rates for the roots," says Johnsen. "Longleaf pines have large taproots and are long lived, so they might store lots of carbon underground."

Johnsen's team will look closely at belowground black carbon, the sooty charcoal residue from incomplete burning of biomass deposited by wildfires and by prescribed fires used to manage fire-adapted species like longleaf pine. SRS scientists will use lab techniques to separate the black carbon in soil from other forms of carbon, providing data for the model of carbon's belowground cycle while quantifying the role of black carbon in removing carbon from the atmosphere.

The project team will collect their data from three military bases in the Southeast where longleaf pine forests flourished in the past: Fort Polk, LA; Fort Benning, GA; and Camp Lejeune, NC. Once covering some 90 million acres in the South, longleaf pine forests were the largest temperate forest type in the United States, but have been in decline for decades because of land clearing for crops and pastures, logging, and other forest products. Longleaf pine ecosystems are some of the most diverse in the nation; nearly two-thirds of all declining, threatened, or endangered species in the Southeast call them home.

The carbon cycle model developed by project collaborators will support DOD's continuing transition towards an ecological forestry model that protects habitat and offsets carbon emissions while sustaining military operations. Funded by DOD through the Strategic Environmental Research and Development Program, the research project is the most expansive and thorough carbon assessment ever conducted on southern military bases.

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Recommended reading:

Butnor, J.; Johnsen, K.; Samuelson, L.; Pruyn, M. 2009. **Current applications of GPR in forest research.** In: Symposium on the application of geophysics to engineering and environmental problems (SAGEEP) Proceedings. March 29 - April 2, Fort Worth, TX. 885–894.

Sarah Farmer is studying biology, chemistry, and writing at Asheville-Buncombe Technical Community College.

Nosing Out Future Landslides

by James T. Spartz

In the mountains of the Southern Appalachian region, landslides are already common occurrences during major storms. Increases in the frequency of extreme rainfall events predicted under climate change could ramp up the risk of landslides in an area where development and roads steadily crawl up the steep hillsides, replacing trees. In western North Carolina, the **North Carolina Geological Survey** has documented over 2,700 landslides and landslide deposits since its landslide hazard-mapping program started in 2009.

Landslides aren't just about blocked roads and property damage. Case in point: Peeks Creek, North Carolina.

In late 2004, Hurricanes Frances and Ivan tracked over western North Carolina. Ivan dumped about 30 inches of rainfall in 10 days, triggering over 140 landslides. The largest landslide at Peeks Creek in Macon County, NC, killed five people, injured two, and destroyed 15 buildings.

Concern about these disasters sparked scientists at the **SRS Coweeta Hydrologic Laboratory** (Coweeta) to look more closely at the role of vegetation type and topographic position in relation to landslide incidents. They were already starting to suspect that the dominance of the woody evergreen shrubs rhododendron and mountain laurel in the subcanopy of Southern Appalachian forests, when in some topographic positions, might have a destabilizing effect on mountainside soils.

In 2008, SRS research ecologist and Coweeta project leader **Jim Vose**, along with SRS scientist **Chelcy Ford** and University of North Carolina at Chapel Hill colleagues **T.C. Hales** and **Larry Band**, set up an experiment at Coweeta to assess whether the presence of rhododendron, combined with topographic position, could play a part in heightened landslide risk.

In mountainous landscapes such as the Southern Appalachians, the roots of plants help reinforce the stability of soils, reducing landslide potential. Previous research found that root

In 2004, a landslide at Peeks Creek in Macon County, NC, killed five people and destroyed 15 buildings. (photo by Leif Skoogfors, Federal Emergency Management Agency) strength can vary greatly across plant varieties such as trees and shrubs and by topographic position—whether a group of trees or shrubs are on a convex hilltop (nose), steep slope, or concave valley floor (hollow).

"Rhododendron roots have been found to be especially weak, which reduces soil stability in the areas where they dominate," says Vose. "The 2004 Peeks Creek event, which covered about 11,960 square yards, or nearly 2.5 acres, began in an area dominated by rhododendron."

To investigate the relationship between root strength and soil stability, researchers dug pits downslope from 15 individual trees on the Coweeta site. The locations of trees varied from noses to hollows. Root and soil samples were taken below native oak, eastern hemlock, birch, tulip poplar, hickory, and other common tree species. The research team also tested areas below rhododendron thickets.

"We found that rhododendrons had the shallowest, weakest roots, suggesting that the presence of this species lowers the ability of soil to hold together under severe rain conditions in some hollows," says Vose. "Since debris flows usually start in the hollows, those dominated by rhododendron could represent a heightened hazard for landslides."

Since 2008, Coweeta scientists have extended their original experiment on root strength and are working with the North Carolina Geological Survey landslide risk-mapping project to incorporate their findings and climate change factors to improve landslide risk modeling.

"Landslide risk models have tended to simplify the factors they consider because the data are not available," says Vose. "This is especially true when it comes to soil and root strength properties." The new, dynamic landslide risk model will meld refined root cohesion and soil strength models with research-based simulations of water, carbon, and nutrient cycles.

The model will also integrate daily weather information, allowing researchers to better assess the vulnerability of the Southern Appalachian study region to alterations in precipitation under different climate change scenarios. This information will be incorporated into the **Regional Hydro-Ecologic Simulation System** (RHESSys) previously developed for Coweeta and used to generate landslide risk estimates based on forest patterns and change over time combined with the circulation of soil and groundwater throughout the Coweeta catchment. This affords Coweeta scientists greater precision in testing the relationships between roots, topographic position, and landslide risk.

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Recommended reading:

Hales, T.C.; Ford, C.R.; Hwang, T. [and others]. 2009. **Topographic and ecological controls on root reinforcement.** Journal of Geophysical Research. 114(F03013). 17 p. [doi: 10.1029/2008JF001168].

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SRS researchers are studying whether the presence of rhododendron, combined with topographic position, plays a part in heightened landslide risk. (photo by Robert L. Anderson, USDA Forest Service, courtesy of Forestry Images)

The Water Web

by Stephanie Worley Firley

Water quantity and quality issues affect every living thing on Earth, yet, until recently, methods for projecting possible future water supply scenarios were fairly limited. In the late 1990s, SRS scientists participating in several national-scale assessments of climate change science and climate-related impacts discovered "a frustrating lack of landscape-scale, integrated ecosystem models from which to draw projections of future hydrologic conditions," according to research ecologist **Steve McNulty**. So they set out to build their own hydrologic model—known as WaSSI—to examine how long-term climatic changes interacting with human factors could influence water availability.

WaSSI stands for the **Water Supply Stress Index**, which was originally developed in 2005 to assess the impacts of changes in temperature and precipitation, land use, and human population on the relationship between water supply and demand in the southern region of the United States. Now researchers with the **Eastern Forest Environmental Threat Assessment Center** (EFETAC) are expanding its scope.

"WaSSI is a comprehensive model that is being built and validated using data from NASA satellite imagery and measurements from more than 500 individual water and carbon monitoring sites around the world," says **Ge Sun**, EFETAC research hydrologist and WaSSI's lead developer. "It can simulate monthly water supplies as well as carbon sequestration—an essential ecosystem function for regulating climate—for approximately 2,100 watersheds across the entire continental United States."

EFETAC's WaSSI development team, including codevelopers McNulty and research hydrologist **Pete Caldwell**, intend to use the model results to help natural resource managers and policymakers make informed decisions when faced with the uncertainties associated with future environmental change.

"Water is a very powerful controller of ecosystem structure and function," explains Sun. "If you understand a forest's water cycle, you can tell a lot about the carbon cycle, biodiversity, and how the ecosystem will respond to change." WaSSI can also help a variety of other users such as educators, researchers, nongovernmental organizations, and the general public gain insight into the effects of global change on water, carbon, and biodiversity at both local and continental scales.

A range of projects are already using information generated by WaSSI, including Forest Futures projects by both SRS and the Northern Research Station.

The WaSSI model is also reaching an international audience. It has been successfully applied in Mexico and Brazil to help address natural resource and land use challenges, and will be applied to several countries in Africa and Asia to quantify potential impacts of land use practices on water quantity and quality as part of an effort to develop economic incentives for conserving watershed ecosystem services.

"This application of WaSSI represents a true international collaboration effort that benefits many people," says Sun. "This is especially true in regions with limited means for monitoring current or forecasting future water and carbon resources."

Southern forests are among the top providers of water supply in the Nation. (photo by Vekony Zoltan, courtesy of Dreamstime)

WaSSI's initial release as a Web-based application is planned for mid-2011. Once the model is online, users will be able to simulate and graph their own scenarios based on climate variations, land cover changes, and human population growth to assess the effects of multiple stresses on water and carbon cycling. In early 2012, WaSSI will offer users a mapping feature to visualize simulation results. WaSSI's developers say the model will continue to evolve over the next 2 to 5 years.

"We are actively pursuing a number of collaborations with universities and other Federal agencies to further expand WaSSI with additional data on watershed connectivity, seasonal streamflow patterns, water quality, and aquatic species," says McNulty. "Our goal is to produce a truly integrated model that can help answer a range of questions about future water and related issues in a changing world."

WASSI:

www.forestthreats.org/tools/WaSSI

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Recommended reading:

Sun, G.; Caldwell, P.; Noormets, A. [and others]. [In press]. **Upscaling key ecosystem functions across the conterminous United States by a water-centric ecosystem model.** Journal of Geophysical Research. [doi:10.1029/2010JG001573].

Sun, G.; McNulty, S.G.; Moore Myers, J.A.; Cohen, E.C. 2008. **Impacts of climate change, population growth, land use change, and groundwater availability on water supply and demand across the conterminous U.S.** Watershed Update. 6(2). 30 p.

Sun, G.; McNulty, S.G.; Moore Myers, J.A.; Cohen, E.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.

Stephanie Worley Firley is a biological science information specialist with EFETAC in Asheville, NC.

Water supplies in many parts of the United States are likely to decline under future climate change. (photo by USDA Forest Service)

What are WaSSI's Significant Findings?

- Based on the model's results, the WaSSI development team has drawn some general conclusions about future water availability in the United States, including:
- Southern forests are among the top providers of water supply and carbon sequestration in the Nation due to favorable climate conditions in the region for forest growth.
- Water supplies in many parts of the United States are likely to decline under future climate change due to increases in air temperature and declines in precipitation.
- Regardless of climate change, population growth will cause water stress problems in metropolitan areas.
- Predicted land use and land cover changes will have little effect on water quantity and water supply and demand relationships at the regional scale. However, these impacts can be significant for certain watersheds that have high degrees of change in land cover.
- Water stress is seasonal, with stress being highest in summer months when demand is high (mainly for irrigation) and supply is low. Reduction of water use by irrigation and domestic sectors can have a big impact on reducing water stress.
- Predictions of future water resources are uncertain due to uncertainty of climate change directions, especially for the Eastern United States.

Forest Ecosystem Stress in Real time

by Zoë Hoyle

Most climate change models predict drier and warmer conditions across the Southern United States, as well as other parts of the country, which may translate into more frequent and severe drought events. Drought not only impacts water supplies for humans but undermines the health of forest ecosystems by increasing susceptibility to insects, diseases, and wildfire. With an estimated 60 percent of the drinking water of the South coming from forested watersheds—and many forests already stressed—land managers need to start planning now to offset the impacts of climate change.

It seems to make sense to start with the forests that are under the greatest stress at a given time, but up until recently it has been difficult to pinpoint exactly where these are. A new resource, the **Remote Assessment of Forest Ecosystem Stress** (RAFES) network, developed by SRS researchers at the **Coweeta Hydrologic Laboratory** (Coweeta), will provide realtime data on climate impacts in at-risk forest ecosystems, giving managers the time they need to respond.

Traditional weather data on rainfall and temperature provide only a very general measure of the stress forest ecosystems may be experiencing.

RAFES tower at the Coweeta Hydrologic Laboratory in Otto, NC. (photo by Barry Clinton, USDA Forest Service)

"Current approaches are often conducted at too large a spatial scale, do not directly measure climate impacts on tree stress, and are not timely enough for managers to plan responses," says **Barry Clinton**, Coweeta research ecologist who's working on the RAFES project with research ecologist **Chelcy Ford** and project leader **Jim Vose**. "We're developing a fine-scale, realtime tree stress monitoring system that can be cost-effectively deployed across the landscape or strategically located in high-risk areas."

The researchers chose to focus on water availability as a stressor, considering its importance in regulating both forest stress and streamflow. The approach is to monitor levels of moisture-related stress through the continuous sensing of soil water content and availability, soil temperature, woody fuel moisture and temperature, xylem sap flux density—with precipitation, relative humidity, air temperature, and solar radiation as drivers. Data from the sensed parameters are transmitted hourly to the **National Oceanic and Atmospheric Administration**, **Geostationary Operational Environmental Satellite** (GOES), downloaded periodically and archived for analysis.

RAFES stations are made up of solar-powered sensor arrays installed at multiple sites across the Eastern United States. Data from these sensors transmitted in real time to the GOES can be retrieved from any location via the Internet. On select sites, data from the sensor arrays are linked with direct measures of physiologically based indices of tree water stress. Researchers are using these data to develop a PC-based analytical tool that allows managers to monitor and assess the severity of climate-related stress from sites on their own or comparable forests in real time.

So far nine sites have been brought online in the RAFES network at locations that range from the **Santee Experimental Forest** on the South Carolina coast to the **Crossett Experimental Forest** in southern Arkansas to the **Marcell Experimental Forest** in northern Minnesota. Other sites are located in the Southern Appalachians, the Piedmont and the coast of North Carolina. RAFES sites span forest ecosystem types, land use histories, and hydrologic gradients. More are on the way.

Eddy covariance tower installed last year at Coweeta to measure the flow of carbon dioxide and other gases above the forest canopy. The observations made with this system, which is separate from the RAFES system, are critical for detecting variations in carbon and nutrient gases in relation to climate change. (photo by Zoë Hoyle, USDA Forest Service)

"The locations of the first sites reflect a combination of leveraging existing infrastructure and site access," says Clinton. "Our approach to adding additional sites will be to identify forest ecosystems that are particularly susceptible to climate change-related stress. Our goals are to be able to provide spatially and temporally explicit early warnings for managers, and in the bigger picture, to provide realtime information on ecosystem responses to extreme climatic events across representative at-risk forest types—as well as to validate conditions detected with coarser scale data such as satellite imagery."

The RAFES network fits nicely within the framework of current Forest Service efforts to evaluate direct and indirect effects of climate change on forest ecosystems and develop tools and practices for adaptation and mitigation. "This approach is the first attempt to our knowledge to quantify such spatially and temporally explicit stress conditions," says Clinton. "It could prove to be a valuable asset to forest management decisionmaking in the face of predicted climate change."

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More Fuel for Fire?

by Susan Andrew

Fire has been a fact of life for millennia in the South, shaping the range and ecology of pine, certain oak, and palm forests. But along with shrinking polar ice and rising sea levels, there is general agreement among climate scientists that climate change will probably increase both the intensity and frequency of fire in the southern landscape.

In its 2007 assessment, the **UN Intergovernmental Panel on Climate Change** cited multiple studies that link the spread of wildfires to the warmer, drier conditions already found in many regions due to rising temperatures from climate change. General circulation models used for weather and climate forecasting predict that by the end of this century, there will be an overall warming and drying trend in a large portion of the subtropics and middle latitudes of the world, including the Southeastern United States—conditions that are expected to also bring an increase in wildfires.

Current SRS research confirms these predictions. A study published last year by **SRS Center for Forest Disturbance Research** researchers **Yongqiang Liu, John Stanturf,** and **Scott Goodrick** examines global and regional wildfire potential using the Keetch-Byram Drought Index (KBDI). This tool was developed in the 1960s by two SRS scientists and has become a widely used estimate of landscape fire potential. A high KBDI value means an increased flammability of organic material on the forest floor that contributes to greater fire intensity. With higher values of KBDI, wildland fires are more intense and spread faster.

SRS researchers calculated future KBDI for the region using projections of temperature and precipitation provided by a regional climate model. They found that fire potential increases across the South in the near future (2041 to 2070), most significantly during summer and fall. They also found an increase in the length of the fire season, with the greatest increase in the Appalachian Mountain region, where the current fire season of 4 months (July to October) is projected to grow to 7 months (April to October) by the end of this century.

"We're projecting an extended fire season, including in the Coastal Plain, where those afternoon thunderstorms that can help put out fires may have a delayed onset," says Goodrick. In addition, when they project forward towards the end of the century using a model that reproduces current conditions, "we see a slight increase in dryness in May and June—that's when a lot of our acres burn. A small change at that time of year means that we'll be fighting more significant

Climate change will probably increase both the intensity and frequency of fire in the southern landscape. (photo courtesy of the U.S. Fish and Wildlife Service)

SRS research meteorologist Yongqiang Liu measures smoke from a fire plume in the field. (photo by USDA Forest Service)

fires then. At the very time when we have our peak fire conditions, our conditions are going to be worse."

In another recent study by Liu and colleagues from Auburn University, the authors predict changes in fuel loads in response to projected changes in climate in the South for the period 2002 to 2050. The researchers found that by 2050, reduced precipitation will lead to a small decline in fuel load for the region as a whole because of reduced forest growth. This will be the case, the researchers argue, despite projections of increased forest growth driven by CO_2 availability and increased nitrogen deposition. However, this study revealed a lot of variability across the South when it comes to fuel loads, owing to different climate effects anticipated in various places. For instance, a decline in precipitation in the northern inland section of the region may lead to a 20-percent reduction in fuel load for the forests of Tennessee and Kentucky, while elevated precipitation and decreased daily mean temperatures in coastal areas of Virginia and the Carolinas may result in increased fuel loads there.

Burning to Reduce the Risk

SRS efforts to understand wildfire trends in a time of climate change can help define management options for mitigating impacts. One management option is prescribed burning, which reduces understory fuels, lowering the risk of wildfires. "Some case studies have shown that the number of wildfires in specific forests has decreased gradually in the past two decades with the increased use of prescribed burning," says Liu. "A need for more extensive use of this tool is expected in the future in the face of the projected increase in wildfire potential."

An oft-cited prediction for the South in a time of climate change is stronger and more frequent tropical storms. Goodrick says one area he's pursuing relates to how these storms and wildfires interact. After a major tropical storm, there's a lot more fuel on the ground, including whole trees knocked down by wind. But the result isn't always what you would expect. "In a moist climate, big logs don't necessarily dry out enough to be part of the fire problem," says Goodrick. "In some conditions they can actually help to reduce fire, because they're still too moist to burn the next year. More 'fuel' doesn't always mean more fire."

Goodrick sees a take-home message for forest managers here. "The standard management response after a major wind event is extensive salvage logging," he says. "But it may not be the best answer, because you may be removing something that can actually reduce fire."

"Wildfire is likely to play a larger role in southern ecosystems. The exact nature of that role will be determined by how the vegetation responds, and how fuel accumulation rates change," says Goodrick. "In the future, fire conditions are likely to be bad, but due to the possibility of lower fuel loads, they won't be as bad as they could have been. Yet even under the best foreseeable future, wildfire is still likely to be worse than it is today."

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Recommended reading:

Liu, Y.-Q.; Stanturf, J.; Goodrick, S. 2009. **Trends in global wildfire potential in a changing climate.** Forest Ecology and Management. 259: 685–697.

Liu, Y.-Q.; Stanturf, J.; Goodrick, S. 2010. **Wildfire potential evaluation during a drought event with a regional climate model and NDVI.** Ecological Informatics. 5: 418–428.

Zhang, C.; Tian, H.; Wang, Yuhang [and others]. 2010. **Predicting response of fuel load to future changes in climate and atmospheric composition in the Southern United States.** Forest Ecology and Management. 260: 556–564.

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CRAFTING FUTURE FORESTS

by Zoë Hoyle

Successful restoration of longleaf pine forests requires frequent prescribed burning. (photo by USDA Forest Service)

Managing our national forests has always involved responding to disturbance—from weather, diseases and insects, wildfire, and now, the impacts of climate change. Since the National Environmental Policy Act (NEPA) passed in 1970, managing national forests has also involved taking into account what the public thinks about proposed plans and actions. In the past, conflicts among competing points of view during the NEPA process have often resulted in long delays and sometimes in the abandonment of proposed actions.

These days, there are even more plans and proposed actions for national forests in the offing, many of them orchestrated around the **Forest Service *National Roadmap for Responding to Climate Change***, a framework developed by the agency for long-term planning. To prepare for climate change impacts, the roadmap supports restoring forests to a healthy functioning condition, an aim that might seem to invite public applause rather than controversy, but on the ground, the actions intended to restore forests may not always be acceptable to everyone.

Take for example, longleaf pine restoration.

Before European settlement, longleaf pine forests covered over 90 million acres in the South. Today, barely 3 million acres remain. There's strong interest in restoring longleaf pine forests and their unique ecosystems, which are more resilient to insect attacks and hurricane winds than the loblolly forests that have largely replaced them. This resilience moves longleaf pine restoration from a good idea to an attractive strategy to address the impacts of climate change.

So what's the problem?

The South is a place of unabated population growth, where more and more people are building their homes near once remote forests. Bringing back longleaf pine into areas now forested with mixed pines and hardwoods requires frequent prescribed burning, which generates smoke that people who live nearby may not be willing to tolerate. Burning less frequently or only when smoke conflicts are unlikely means less fire, which will eventually defeat the restoration. In this case, uncertainty and the anticipation of conflict could lead managers to back off plans for longleaf pine restoration in certain areas as just too much trouble. If long-range planning could actually predict where such conflicts would or would not arise, our landscapes on the whole could be better managed.

Fortunately, SRS scientists have developed a new resource, the **Comparative Risk Assessment Framework and Tools** (CRAFT), to help natural resource managers and stakeholders work through land management decisions and find common ground, sometimes by coming up with unexpected solutions.

Virtual Common Ground

Headquartered at SRS, the **Eastern Forest Environmental Threat Assessment Center** (EFETAC) was formed in 2005 to develop new technology and tools to anticipate and respond to emerging eastern forest threats, and to deliver these tools to other scientists, managers, and stakeholders involved in natural resource planning and decisionmaking.

In fall 2009, EFETAC launched CRAFT as a user-friendly Web-based system designed to support natural resource managers in addressing the uncertainties inherent in land management decisions. Building on the NEPA framework, CRAFT offers a simple and comprehensive approach that teams of managers and stakeholders can use to look at the risks and tradeoffs associated with different management scenarios.

"It's all about tradeoffs," says **Steve Norman**, EFETAC research ecologist who helped develop CRAFT. "Before NEPA, land managers made decisions by focusing on individual threats or values. Today, even with NEPA in place, the broader effects that those decisions could have on other values are still difficult to predict. CRAFT is a way to tease out those broader values and infer likely consequences."

CRAFT was designed to capture this broader view of what's likely to happen in a given situation and to ensure that the values that are most likely to be affected are adequately considered. As its name indicates, CRAFT is about comparative risk assessment, allowing users to weigh the likely impacts to values—what they care about—based on the chance that the action will be successful. This approach provides ways to work through tradeoffs while formally taking uncertainty into consideration.

The process starts when a diverse group of stakeholders or a management team sits down at the table to examine values and address how they are affected by the problem at hand and possible solutions. Through the process, team members explore the probable and possible outcomes of different actions—including the decision not to act—while broadening their own understanding of conflicts, tradeoffs, and the uncertainties and unintended effects that follow from decision alternatives.

"When we developed CRAFT, we borrowed the best ideas we could find from the emerging fields of decision science and risk assessment," says Norman. "This included ways to organize values, vet cause and effect relationships, and formally model uncertainty and decision options."

To develop CRAFT, EFETAC partnered with the University of North Carolina Asheville's **National Environmental Modeling and Analysis Center** (NEMAC), which created a unique array of Web-based resources, including the CRAFTiPedia—a "wiki" style reference database and glossary. The CRAFT online tool can store and share the diagrams, text, tables, data, and models created during each decisionmaking project. NEMAC also provides assistance and training on using CRAFT.

Although designed to follow NEPA requirements, CRAFT can be used by a much broader range of audiences and for regional and even national-level issues. For example, in 2009, the first CRAFT workshop included people from the Forest Service, the National Oceanic and Atmospheric Administration's National Climatic Data Center, the City of Asheville, the Southern Group of State Foresters, and The Nature Conservancy, in an introductory exercise aimed at addressing climate change impacts on the Southern Appalachians.

The latest application of CRAFT involves the **Cohesive Wildland Fire Strategy**, a new multiagency wildfire strategy that aligns with the Forest Service roadmap for responding to the climate change that is projected to increase the frequency and extent of forest fires across the United States. Led by EFETAC's director **Danny Lee**, who helped develop CRAFT, the all-lands approach of the fire strategy has three main goals: using ecosystem restoration to build fire-adapted communities, building fire-adapted human communities by sharing knowledge and technical resources, and responding appropriately to wildfire.

"Applying CRAFT to address wildfire issues in the Southeast is exciting," says Norman. "Fire is necessary for the resilience of many southern ecosystems, and prescribed fire use can conflict with trends in urban development." CRAFT provides the framework to get at these issues and more—and just maybe some solutions no one's thought of yet.

CRAFT Web site:

CRAFT.forestthreats.org.

For more information:

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Recommended reading:

Hicks, J.; Pierce, T. 2009. **CRAFTing better decisions: creating a link between belief networks and GIS.** ArcUser. Fall: 20–23.

Climate Change Invasions

by Teresa Jackson

The **Eastern Forest Environmental Threat Assessment Center** (EFETAC) uses modeling tools to assess the effects of climate change on invasive plant species. Climate change, as a major and growing disturbance agent, can have wide ranging effects on invasive species. Studies show that nonnative plants, especially invasive species, appear to thrive during times of climate change, as it creates niches and opportunities that promote invasion.

EFETAC researchers use a wide range of modeling and simulation approaches to make comprehensive comparisons between the habitats and geographical distributions of native and nonnative invasive plant species that help them to predict how expected climate change will affect the distributions of plant species in a given area. Geographic Information System (GIS) remote sensing tools are also used to assist the modeling process and to visually map out results that are easy to understand by both scientists and land managers.

"Effective management of invasive plant species requires a basic understanding of plant biology and ecology, particularly how species interact with each other and with the environment," says **Qinfeng Guo**, EFETAC research ecologist based in Asheville, NC. "This includes looking at how the life history and genetic traits of invasive plants may be linked to rapid and widespread invasion under current and projected future climate conditions."

Conducting both field and experimental research in diverse ecosystems across the United States and internationally allows scientists to collect life history and habitat data from both native and exotic regions that can be used to explain the current distribution of invasive plant species and to predict future spread under changing climate and land use change scenarios.

Many invasive plants have been introduced to the United States in a relatively short period of time.

Some nonnative invasive plants species such as cogongrass appear to thrive under climate change. (photo by Chris Evans, courtesy of Forestry Images)

Although some presently occupy smaller ranges relative to their native ranges, they have great potential to spread quickly and widely. Knowing which species are likely to do so based on their traits is critically needed to take early actions in prevention and control.

"The ultimate goal of EFETAC research is to preserve native biodiversity and to manage invasive species," says Guo.

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Recommended reading:

Guo, Q.; Ricklefs, R. 2010. **Domestic exotics and the perception of invisibility.** Diversity and Distributions. 16: 1034–1039.

Cogongrass infestation in a pine plantation. (photo by Chris Evans, courtesy of Forestry Images)

New Guide to Managing Invasive Plants

Many landowners are continuously plagued with unidentifiable annoying weeds and grasses that are resilient to herbicides. Some of these are nonnative invasives, plant species that have arrived without the natural predators and diseases that keep native plants in natural balance. Many have hybridized and increase across the landscape with little opposition.

Nonnative plants have hitchhiked their way into flower beds, gardens, and yards of landowners in the South for decades, invading and often harming forests and other natural areas by pushing out native plants and degrading wildlife habitat. These exotic plants often reduce forest productivity, wildlife diversity, and water quality and quantity.

The prevention and management strategies that landowners have been looking for to help control these unwanted resilient plants are now available in a new 120-page guide, ***A Management Guide for Invasive Plants in Southern Forests.*** The guide provides effective control prescriptions for 56 nonnative plants and plant groups and gives homeowners, gardeners, land managers, and others information needed to achieve land rehabilitation and restoration.

Jim Miller, an emeritus SRS research ecologist based in Auburn, AL, and one of the foremost authorities on invasive plants in the South, authored the guide with **Steven Manning**, president of Invasive Plant Control, Inc., and **Stephen Enloe**, weed management specialist at Auburn University.

Request your free copy today by sending your name and complete mailing address, along with book title, author, and publication number GTR–SRS–131 to: pubrequest@fs.fed.us, or by calling 828–257–4830. The 120-page guide is also available on the SRS Web site at www.srs.fs.usda.gov/pubs/36915.

Experimental Forests

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

NEW PRODUCTS

from the Southern Research Station…

Forest Ecosystem Restoration and Management

1 Barnett, J.P. 2011. **Faces from the past: profiles of those who led restoration of the South's forests.** Gen. Tech. Rep. SRS–133. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 68 p.

Early in the 20th century, the forests in the South were devastated by aggressive harvesting and many millions of acres of forest land needed reforestation. Foresighted individuals began a committed effort to restore this land to a productive condition. This effort required dedication, cooperation, and leadership. A small cadre of individuals led the restoration of the South's forests that became the basis of the South's economy. Many of these individuals are profiled in this document.

2 Bragg, D.C.; Shelton, M.G. 2011. **Lessons from 72 years of monitoring a once-cut pine-hardwood stand on the Crossett Experimental Forest, Arkansas, U.S.A.** Forest Ecology and Management. 261(5): 911–922.

The Crossett Experimental Forest was established in 1934 to provide landowners in the Upper West Gulf Coastal Plain with reliable, science-based advice on how to manage their loblolly (*Pinus taeda*) and shortleaf (*P. echinata*) pine-dominated forests. A key component of this program was the establishment of an unmanaged control, currently known as the Russell R. Reynolds Research Natural Area (RRNA). Originally intended to show how the lack of regulation reduced sawtimber production compared to more intensively managed stands, the once-cut RRNA is now recognized as an increasingly scarce example of an undisturbed, mature pine-hardwood stand. This, in turn, has led to studies on forest succession, coarse woody debris, old-growth stand structure conditions, and biomass accumulation patterns.

3 Kubisiak, T.L.; Anderson, C.L.; Amerson, H.V. [and others]. 2011. **A genomic map enriched for markers linked to Avr1 in *Cronartium quercuum f.sp. fusiforme*.** Fungal Genetics and Biology. 48(3): 266–274.

A novel approach is presented to map avirulence gene Avr1 in the basidiomycete *Cronartium quercuum f.sp. fusiforme*, the causal agent of fusiform rust disease in pines. DNA markers tightly linked to resistance gene Fr1 in loblolly pine tree 10–5 were used to classify 10–5 seedling progeny as either resistant or susceptible. A single dikaryotic isolate (P2) heterozygous at the corresponding Avr1 gene was developed by crossing Fr1 avirulent isolate SC20–21 with Fr1 virulent isolate NC2–40. Bulk basidiospore inoculum derived from isolate P2 was used to challenge the pine progeny. The ability to unambiguously marker classify

10–5 progeny as resistant (selecting for virulence) or susceptible (nonselecting) permitted the genetic mapping of the corresponding Avr1 gene by bulked segregant analysis. Using this approach, 14 genetic markers significantly linked to Avr1 were identified and placed within the context of a genome-wide linkage map produced for isolate P2 using samples from susceptible seedlings.

4 Sayer, M.A.S.; Sung, S.-J.S.; Haywood, J.D. 2011. **Longleaf pine root system development and seedling quality in response to copper root pruning and cavity size.** Southern Journal of Applied Forestry. 35(1): 5–11.

Cultural practices that modify root system structure in the plug of container grown seedlings have the potential to improve root system function after planting. Our objective was to assess how copper root pruning affects the quality and root system development of longleaf pine seedlings grown in three cavity sizes in a greenhouse. Copper root pruning increased seedling size, the allocation of root system dry weight to the taproot, and the fraction of fibrous root mass allocated to secondary lateral roots compared with primary lateral roots. It decreased the allocation of root system dry weight to primary lateral roots and led to a distribution of root growth potential that more closely resembled the root growth of naturally sown seedlings. These effects of copper root pruning may benefit longleaf pine establishment. However, because copper root pruning increased competition for cavity growing space among the taproot and fibrous roots, we suggest that recommendations regarding cavity size and seedling quality parameters be tailored for copper-coated cavities.

5 U.S. Department of Agriculture Forest Service, Southern Research Station. 2010. **Upland hardwood silviculture** [DVD]. Science Update SRS–27. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station.

The Upland Hardwood Ecology and Management unit of the Southern Research Station offers a week-long course that provides practicing foresters with information about current silvicultural practices and emerging issues based on scientific research and applied techniques that affect managing upland hardwoods. This DVD captures the course that took place in July 2007. "Upland Hardwood Silviculture" features 7 modules with 16 topics presented by Forest Service and university leaders. Modules include forest health, management objectives, site classification, stand management, regeneration, restoration of American chestnut, and wildlife.

Forest Values, Uses, and Policies

6 Eberhardt, T.L.; Catallo, W.J.; Shupe, T.F. 2010. **Hydrothermal transformation of Chinese privet seed biomass to gas-phase and semi-volatile products.** Bioresource Technology. 101: 4198–4204.

Hydrothermal (HT) treatment of seeds from Chinese privet (*Ligustrum sinense*), a nonnative and invasive species in the Southeastern United States, was examined with respect to the generation of gas-phase and semivolatile organic chemicals of industrial importance from a lipid-rich biomass resource. Aqueous seed slurries were transformed into biphasic liquid systems comprised of a milky aqueous phase overlain by a black organic layer. Present in the headspace were elevated levels of CO_2 and acetic acid. Analysis of the semivolatiles by GC–MS showed the formation of alkyl substituted benzenes, oxygenated cyclic alkenes, phenol, substituted phenolics, and alkyl substituted pyridines. Compared to immature seeds, mature seeds gave

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Large-flowered trillium. (photo by USDA Forest Service) high relative amounts of oxygenated cyclic alkenes and alkyl pyridines. Estimates of lignin and protein contents showed no definite trend that could be linked to the HT data. The proportion of aromatic HT products appeared to derive primarily from the proportion of extractives. Thus, variations in extractives yields impact HT product yields and thereby demonstrate the importance of timing in feedstock collection to favor targeted HT products.

7 Escobedo, F.; Varela, S.; Zhao, M. [and others]. 2010. **Analyzing the efficacy of subtropical urban forests in offsetting carbon emissions from cities.** Environmental Science & Policy. 13: 362–372.

Urban forest management and policies have been promoted as a tool to mitigate carbon dioxide (CO_2) emissions. This study used existing CO_2 reduction measures from subtropical Miami-Dade and Gainesville, FL, and modeled carbon storage and sequestration by trees to analyze policies that use urban forests to offset carbon emissions. Urban forests in Gainesville have greater tree density, store more carbon, and present lower per-tree sequestration rates than Miami-Dade as a result of environmental conditions and urbanization patterns. Areas characterized by natural pine-oak forests, mangroves, and stands of highly invasive trees were most apt at sequestering CO_2. Results indicate that urban tree sequestration offsets CO_2 emissions and, relative to total citywide emissions, is moderately effective at 3.4 and 1.8 percent in Gainesville and Miami-Dade, respectively. Moreover, converting available nontreed areas into urban forests would not increase overall CO_2 emission reductions substantially. Current CO_2 sequestration by trees was comparable to implemented CO_2 reduction policies. However, long-term objectives, multiple ecosystem services, costs, community needs, and preservation of existing forests should be considered when managing trees for climate change mitigation and other ecosystem services.

8 Johnson, C.Y.; Halfacre, A.C.; Hurley, P.T. 2009. **Resistant place identities in rural Charleston County, South Carolina: cultural, environmental, and racial politics in the Sewee to Santee area.** Human Ecology Review. 16(1) :1–16.

The cultural and political implications of landscape change and urban growth in the Western United States are well documented. However, comparatively little scholarship has examined the effects of urbanization on sense of place in the Southern United States. We contribute to the literature on competing place meanings with a case study from the rural "Sewee to Santee" region of northern Charleston County, SC. Our research highlights conflicting cultural, environmental, and racial politics and their roles in struggles over place meanings. Using focus groups, interviews with elected officials, and participant observation, we document initial African-American resistance and eventual compliance with the prevailing antisprawl discourse and associated sense of place promoted by the Charleston County Planning Commission and others. Our research suggests that dynamics driving development in the rural, U.S. South are similar in kind to those in the Third World where natural resource decisions are informed by class, cultural, and racial politics.

9 Staudhammer, C.; Hermansen-Báez, L.A.; Carter, D.; Macie, E.A. 2011. **Wood to energy: using southern interface fuels for bioenergy.** Gen. Tech. Rep. SRS–132. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 90 p.

This publication aims to increase awareness of potential uses for woody biomass in the Southern Wildland-Urban Interface (WUI) and to disseminate knowledge about putting bioenergy production systems in place, while addressing issues unique to WUI areas. Chapter topics include woody biomass sources in the wildland-urban interface; harvesting, preprocessing, and delivery of woody biomass in the wildland-urban interface; biomass conversion to energy and fuels; the economic availability of woody biomass; economic impact analysis of woody biomass energy development; and public perceptions of using wood for fuel.

Forest Watershed Science

10 Bryant, M.D. 2010. **Past and present aquatic habitats and fish populations of the Yazoo-Mississippi Delta.** Gen. Tech. Rep. SRS–130. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 28 p.

The goal of this review and synthesis of the literature is to describe the major processes that shape and influence the aquatic habitats and fish communities in the Yazoo-Mississippi Delta (YMD) and to outline a program of research. The YMD is influenced by the large geographic and temporal scales of the Mississippi River watershed. It extends over 41 percent of the contiguous United States. The Mississippi River has existed in its current location for more than 1.2 million years, and ancient fish species are still present in the watershed. Seasonal floods are keystone events in the YMD, but the process is altered substantially from its previous natural state. Levees, flood control structures, land use practices, and loss of large wood in river channels have modified natural processes throughout most of the YMD. However, most of the larger fish species present during aboriginal occupation of the YMD are still present. Given the large-scale loss of habitat throughout the YMD and the deterioration of water quality, the abundance and diversity of fish likely have declined. In the past few years, management of aquatic habitats in the YMD has centered on mitigating and preventing some of the adverse effects of anthropogenic disturbance. The research approach proposed in this paper provides a model to develop an understanding of the fish and aquatic habitat that can contribute to a sustainable restoration program.

11 Clinton, B.D. 2011. **Stream water responses to timber harvest: riparian buffer width effectiveness.** Forest Ecology and Management. 261: 979–988.

Vegetated riparian buffers are critical for protecting aquatic and terrestrial processes and habitats in Southern Appalachian ecosystems. In this case study, we examined the effect of riparian buffer width on streamwater quality following upland forest management activities in four headwater catchments. Three riparian buffer widths were delineated prior to cutting: 0 m (no buffer), 10 m, and 30 m, and one reference site. A 2-age prescription timber harvest was conducted on all cut sites with a target residual basal area of approximately 4.0 m 2 ha^{-1}. Stream water chemistry, temperature, and total suspended solids (TSS) were used as metrics of water quality. Pretreatment concentrations of all solutes were similar to conditions found in other headwater streams at similar topographic positions around the region. The greatest responses to cutting occurred on the no-buffer site. Compared with preharvest levels on the no-buffer site, stream nitrate concentration [(NO3–N)] increased twofold during both base and stormflow following harvest, and all base cations increased in concentration. The other sites did not show increases in [NO3–N] and very small or no responses in other stream chemistry parameters. There was no TSS response at stormflow on any site, and during baseflow, TSS decreased on all but the no-buffer site. Streamwater temperature increased during the summer on the no-buffer site. Although alternative land uses may have different requirements, these results suggest that for riparian buffer widths of 10 m and wider, the forest harvest activities implemented in this study did not substantially impact streamwater quality. Hence, 10-m wide buffers in these ecosystems may provide effective protection with respect to streamwater chemistry, TSS, and temperature.


Hummingbird migration patterns are changing in relation to climate. (photo by USDA Forest Service)

12 Dosskey, M.G.; Vidon, P.; Gurwick, N.P. [and others]. 2010. **The role of riparian vegetation in protecting and improving chemical water quality in streams.** Journal of the American Water Resources Association. 46 (2): 261–277.

We review the research literature and summarize the major processes by which riparian vegetation influences chemical water quality in streams, as well as how these processes vary among vegetation types, and discuss how these processes respond to removal and restoration of riparian vegetation and thereby determine the timing and level of response in streamwater quality. Our emphasis is on the role that riparian vegetation plays in protecting streams from nonpoint-source pollutants and in improving the quality of degraded streamwater. Riparian vegetation influences streamwater chemistry through diverse processes including direct chemical uptake and indirect influences such as by supply of organic matter to soils and channels, modification of water movement, and stabilization of soil. Whether stream chemistry can be managed effectively through deliberate selection and management of vegetation type, however, remains uncertain because few studies have been conducted on broad suites of processes that may include compensating or reinforcing interactions. Scant research has focused directly on the response of streamwater chemistry to the loss of riparian vegetation or its restoration. Our analysis suggests that the level and time frame of a response to restoration depends strongly on the degree and time frame of vegetation loss.

13 Elliott, K. J.; Vose, J. 2011. **The contribution of the Coweeta Hydrologic Laboratory to developing and understanding of long-term (1934-2008) changes in managed and unmanaged forests.** Forest Ecology and Management. 261(5): 900–910.

Coweeta Hydrologic Laboratory (Coweeta) in western North Carolina is one of 82 experimental forests and ranges located throughout the United States and Puerto Rico. Since its establishment in 1934, the wealth and breadth of scientific knowledge gained from Coweeta research has provided both public and private land managers information on forest land management. We described the early watershed research at Coweeta and used long-term measurements and inventories (from 1934 to 2008) to: (1) explore the influences of large-scale disturbances and vegetation responses on ecosystem processes and (2) assess the long-term and short-term impacts of an exotic, invasive species on a Southern Appalachian deciduous forest. We focused on changes in vegetation patterns influenced by natural and managed disturbances and then described the linkages between long-term vegetation measurements and water yield and quality responses. For natural disturbances, we used a network of over 900 permanent vegetation plots established in reference watersheds and unmanaged areas first

Rock formation in Ozark National Forest. (photo by USDA Forest Service)

measured in 1934. For the managed disturbances, clearcuts and species conversion experiments, vegetation was measured in permanent plots within treated watersheds before and after treatment. Long-term climatic, hydrologic, biogeochemical, and vegetation databases coupled with process-based ecohydrology and ecophysiology models are essential to understanding broader and more complex environmental issues such as climate change, carbon cycling, atmospheric deposition, and water supply and quality.

Natural Resources Inventory and Monitoring

14 Bentley, J.W.; Johnson, T.G. 2010. **North Carolina harvest and utilization study, 2007.** Resour. Bull. SRS–167. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 27 p.

In 2007, a harvest and utilization study was conducted on 83 operations throughout North Carolina. There were 2,119 total trees measured: 1,323 or 62 percent were softwood, while 796 or 38 percent were hardwood. Results from this study showed that 85 percent of the total softwood volume measured was utilized for a product, and 15 percent was left as logging residue. Seventy-seven percent of the total hardwood volume measured was utilized for a product, while 23 percent was left as logging residue.

15 Conner, R.C.; Johnson, T.G. 2011. **Estimate of biomass in logging residue and standing residual inventory following tree-harvest activity on timberland acres in the southern region.** Resour. Bull. SRS–169. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 25 p.

This report provides estimates of biomass (green tons) in logging residue and standing residual inventory on timberland acres with evidence of tree cutting. Biomass as defined by Forest Inventory and Analysis is the aboveground dry weight of wood in the bole and limbs of live trees ≥ 1-inch diameter at breast height (dbh), and excludes tree foliage, seedlings, and understory vegetation. Total timberland area with evidence of tree cutting averaged just over 6.0 million acres per year for all 13 Southern states over a 14-year period from 1994 to 2008. Final harvest was the primary type of cutting and averaged almost 2.3 million acres. Partial harvest and commercial thinning accounted for 1.8 million acres, and 1.7 million acres, respectively. As a result of annual tree cutting of all types in all 13 Southern states, a total of > 737 million green tons of residual biomass in standing live trees remained after harvesting. Of that volume, biomass in all-live residual inventory trees (≥ 1-inch dbh) on final harvest acres amounted to nearly 457 million green tons. Biomass in rough and rotten trees from all other cutting combined totaled just over 280 million green tons. If recovered, this material could be used to help supply a biofuels industry in the South.

16 Johnson, T.G.; Steppleton, C.D. 2011. **Southern pulpwood production, 2009**. Resour. Bull. SRS–168. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 38 p.

The South's production of pulpwood declined from 67.0 million cords in 2008 to 61.2 million cords in 2009. Roundwood production declined by 2.3 million cords to 46.5 million cords and accounted for 76 percent of the South's total pulpwood production. The use of wood residue dropped 3.6 million cords, from 18.2 million cords in 2008 to 14.6 million cords in 2009. Georgia and Alabama led the South in total production, with 10.0 and 9.4 million cords, respectively. In 2009, 83 mills were operating and drawing wood from the 13 Southern states. Pulping capacity of southern mills increased from 124,679 tons per day in 2008 to 123,368 tons per day in 2009.

17 Oswalt, C.M.; Oswalt, S.N.; Brandeis, T.J. 2010. **Big trees in the southern forest inventory.** Res. Note SRS–19. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 36 p.

Big trees fascinate people worldwide, inspiring respect, awe, and oftentimes, even controversy. This paper uses a modified version of American Forests' Big Trees Measuring Guide point system (May 1990) to rank trees sampled between January of 1998 and September of 2007 on over 89,000 plots by the USDA Forest Service, Forest Inventory and Analysis Program in the Southern United States. Trees were ranked across all states and for each state. There were 1,354,965 trees from 12 continental states, Puerto Rico, and the U.S. Virgin Islands sampled. A bald cypress (*Taxodium distichum*) in Arkansas was the biggest tree (according to the point system) recorded in the South, with a diameter of 78.5 inches and a height of 93 feet (total points = 339.615). The tallest tree recorded in the South was a 152-foot tall pecan (*Carya illinoinensis*) in Mississippi (total points = 321.960), while the tree with the largest diameter was the bald cypress mentioned above.

Threats to Forest Health

18 Guo, Q.; Ricklefs, R. 2010. **Domestic exotics and the perception of invisibility.** Diversity and Distributions. 16: 1034–1039.

Susceptibility of an area to invasion by exotic species is often judged by the fraction of introduced species in the local biota. However, the degree of invasion, particularly in mainland areas, has often been underestimated because of the exclusion of "domestic exotics" in calculations. Because all introduced species on islands are considered as exotics, this contributes to the perception that islands are more susceptible to invasion than are continental regions. Here, we determine the contribution of domestic exotic species to the degree of invasion (exotic fraction) in mainland areas. We quantify the relationships of exotic fraction to the area, human population density, and land use within each of the 48 conterminous U.S. states to identify mechanisms that potentially influence the degree of invasion. For each of the 48 conterminous U.S. states, we compiled the number of species introduced from outside the United States ('foreign exotics') and the number of exotics introduced from other conterminous U.S. states ('domestic exotics'). We found that: (1) the exotic fraction inevitably decreases with increasing area as the pool of potential exotic species decreases, (2) exotic richness of areas within large mainland regions is underestimated to the extent that species introduced among areas within a region are considered as natives, and (3) human activities contribute disproportionately more exotics to smaller than to larger administrative areas. How we define 'exotic' influences how we count nonnative species and perceive invasibility. Excluding domestic exotics in mainland regions leads to a biased perception of increased invasibility on islands, where all introduced species are considered exotic.

19 Liu, Y.; Stanturf, J.A.; Goodrick, S.L. 2010. **Wildfire potential evaluation during a drought event with a regional climate model and NDVI.** Ecological Informatics. 5: 418–428.

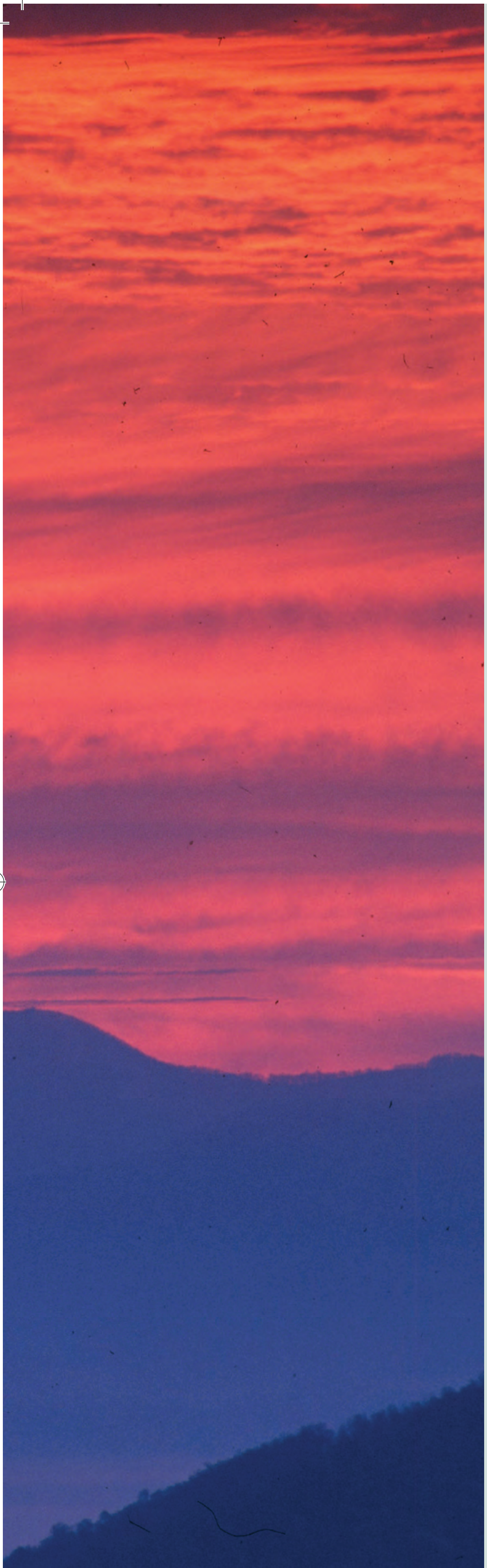
Regional climate modeling is a technique for simulating high-resolution physical processes in the atmosphere, soil, and vegetation. It can be used to evaluate wildfire potential by either providing meteorological conditions for computation of fire indices or predicting soil moisture as a direct measure of fire potential. This study examines these roles using a regional climate model for the drought and wildfire events in 1988 in the Northern United States. The National Center for Atmospheric Research Regional Climate Model was used to conduct simulations of a summer month in each year from 1988 to 1995. The simulated precipitation and maximum surface air temperature were used to calculate the Keetch–Byram Drought Index (KBDI), which is a popular fire potential index. We found that the KBDI increased significantly under the simulated drought condition. The corresponding fire potential was upgraded from moderate for a normal year to high level for the drought year. High fire potential is often an indicator for occurrence of intense and extensive wildfires. The small magnitude of the simulated soil moisture anomalies during the drought event did not provide sufficient evidence for the role of simulated soil moisture as a direct measure of wildfire potential.

20 McNulty, S.G.; Boggs, J.L. 2010. **A conceptual framework: redefining forests soil's critical acid loads under a changing climate.** Environmental Pollution. 158: 2053–2058.

Federal Agencies of several nations have or are currently developing guidelines for critical forest soil acid loads. These guidelines are used to establish regulations designed to maintain atmospheric acid inputs below levels shown to damage forests and streams. Traditionally, when the critical soil acid load exceeds the amount of acid that the ecosystem can absorb, it is believed to potentially impair forest health. The excess over the critical soil acid load is termed the exceedance, and the larger the exceedance, the greater the risk of ecosystem damage. This definition of critical soil acid load applies to exposure of the soil to a single, long-term pollutant, i.e., acidic deposition. However, ecosystems can be simultaneously under multiple ecosystem stresses and a single critical soil acid load level may not accurately reflect ecosystem health risk when subjected to multiple, episodic environmental stress. For example, the Appalachian Mountains of western North Carolina receive some of the highest rates of acidic deposition in the Eastern United States, but these levels are considered to be below the critical acid load that would cause forest damage. The article offers an example showing how the interaction of long-term acid deposition interacted with drought and insect infestation to cause mortality of red spruce in 2001.

21 Miller, J.H.; Manning, S.T.; Enloe, S.F. 2010. **A management guide for invasive plants in southern forests.** Gen. Tech. Rep. SRS–131. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 120 p.

Invasions of nonnative plants into forests of the Southern United States continue to spread and include new species, increasingly eroding forest productivity, hindering forest use and management activities, and degrading diversity and wildlife habitat. This book provides the latest information on how to organize and enact prevention programs, build strategies, implement integrated procedures for management, and proceed towards site rehabilitation and restoration. Effective control prescriptions are provided for 56 nonnative plants and groups currently invading the forests of the 13 southern states.



Nantahala mountain sunrise. (photo by USDA Forest Service)

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

Location and project leader	Name and Web site	Phone
Asheville, NC Katie 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

Location and project leader	Name and Web site	Phone
Gainesville, FL Cassandra Johnson Gaither, Acting	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

Location and project leader	Name and Web site	Phone
Asheville, NC Danny Lee	Eastern Forest Environmental Threat Assessment Center www. forestthreats.org	828-257-4854
Athens, GA Scott Goodrick	Center for Forest Disturbance Science www.srs.fs.usda.gov/disturbance	706-559-4316
Pineville, LA Doug Streett	Insects, Diseases, and Invasive Plants of Southern Forests www.srs.fs.usda.gov/4501	318-473-7232

Forest Watershed Science

Location and project leader	Name and Web site	Phone
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

Location and project leader	Name and Web site	Phone
Knoxville, TN Bill Burkman	Forest Inventory and Analysis www.srsfia2.fs.fed.us	865-862-2000

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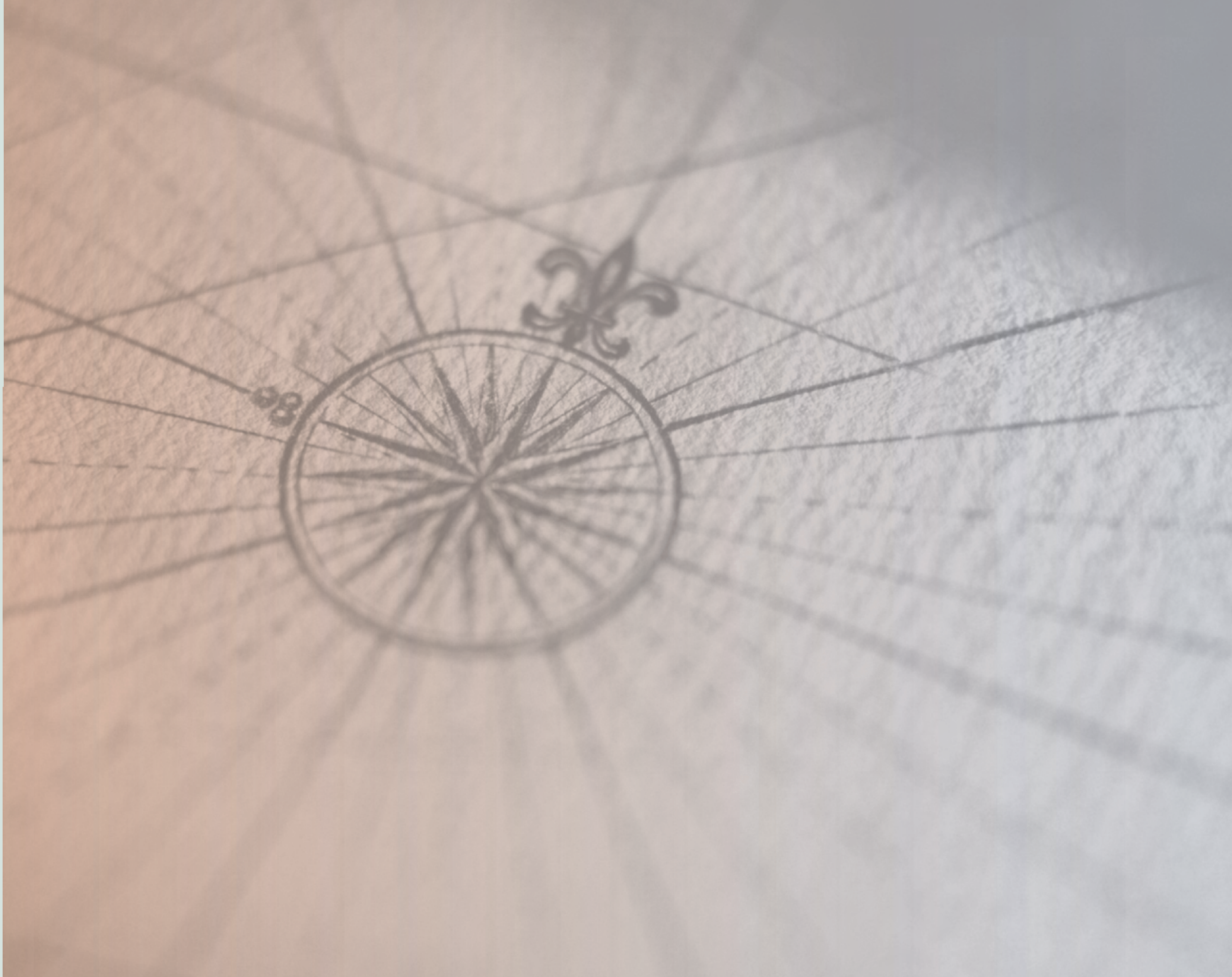
—Kai N. Lee, *The Compass and the Gyroscope—Integrating Science and Politics for the Environment*



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On May 17, 2011, the Forest Service and the Southern Group of State Foresters released the first phase of the Southern Forest Futures Project, a multiyear research effort that forecasts changes in forest conditions in the South between 2010 and 2060. The next issue of Compass will highlight findings from the initial report on urbanization, impacts on water supply, wildfire, and imperiled species.

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September 2009 flood along the Atlantic coast of Georgia. (photo by the National Aeronautics and Space Agency, courtesy of Wikimedia Commons)