Southern Research Station
Global Change Research Strategy
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Compiled and edited by:

Kier Klepzig, Southern Research Station

Zoë Hoyle, Southern Research Station

Stevin Westcott, Southern Research Station

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Executive Summary

Forest planners and managers will not only need the best available science to adapt to changes in local conditions, but also an understanding of how their decisions will play out at broader scales. (Photo courtesy of the USDA Forest Service)

Objective

In keeping with the goals of the Research and Development agenda of the Forest Service, U.S. Department of Agriculture (USDA), the Southern Research Station (SRS) provides the information and technology needed to develop best management practices for the forest lands of the Southern United States, where science-guided actions are needed to sustain ecosystem health, adjust management for ecosystem services ("adaptation"), and increase carbon sequestration ("mitigation"), all under changing climate conditions. The primary focus of the SRS Global Change Research Strategy is to increase understanding of southern forest ecosystems so that they can be managed in a way that sustains and provides ecosystem services for future generations.

Basis

Many of the observed and predicted effects of climate change are tied to temporal and geographic scale. The relative sensitivity of various ecosystems and the services they provide to climate change are also scale dependent.

The ability of forests in the South to adapt to and mitigate climate change will require supporting research that is matched to temporal- and geographic-scale needs (i.e., immediate versus long term and regional versus local). Forest planners and managers will need not only the best available supporting science to adapt to changes in local conditions, but also an understanding of the implications of those decisions within the context of broad regional and national trends driving change at the landscape scale.

The SRS Global Change Research Strategy tiers to the national strategy with emphasis on providing a coordinated scientific response at scales appropriate to land ownerships in the South. This strategy will help ensure research is available to support understanding of southern ecosystem services and address impacts to these services at appropriate temporal and geographic scales.

Approach

The SRS Global Change Research Strategy follows that of the Forest Service national strategy by balancing research across a range of management, science, and science delivery actions aimed at developing adaptation and mitigation approaches to sustain healthy ecosystems.

This document (SRS Global Change Research Strategy) describes research goals, research needs, and near-term research products that support those needs and is organized around the following areas:

(Photo courtesy of the USDA Forest Service)

1. **Research to Enhance Ecosystem Sustainability (Adaptation)** focuses on research that will advance management options to enhance ecosystem health and sustainability; ensure ecosystem services such as water, wildlife, biodiversity, recreation, and forest products; and reduce losses of ecosystem function from climate-altered disturbances such as wildfire, insects, and invasive species.
2. **Research to Increase Carbon Sequestration (Mitigation)** focuses on research that will assist managers in (a) enhancing carbon sequestration through actions designed to increase forest growth rates and area of forested lands; (b) enhancing biomass extraction and utilization research; and (c) understanding long-term carbon storage pools.
3. **Research to Provide Decision Support** integrates the first two elements by developing decision-support tools and approaches for land managers, policymakers, and planners.
4. **Shared Research Needs: Infrastructure, Scientific Collaboration, and Science Delivery** focuses on the infrastructure and collaboration needed to generate new knowledge and applications for adaptation, mitigation, decision support, and science delivery.

Overview

Most of the forested acres in the South are privately owned. Changing climate patterns present challenges that must be addressed across boundaries with multiple partners. (Photo courtesy of the USDA Forest Service)

The South's forests filter water, ensuring quality drinking supplies to about 60 percent of the region's people. (Photo courtesy of the USDA Forest Service)

Objective

Beginning with the first tracts of land purchased in the Southeastern United States to establish a National Forest System (NFS), a century of policy and management has evolved to help sustain the diverse forest ecosystems and the variety of ecosystem services that stretch across the region. In contrast to the Western United States, the vast majority of forested acres in the South are held in private rather than public ownership. Held in common across all ownerships is the need for research that supports management objectives of adaptation and mitigation in the face of changing climate patterns.

From the upland hardwood forests of Virginia to the bottomland hardwoods of Mississippi and from the pine stands of Arkansas to the Coastal Plains along the Atlantic and gulf coasts, forests cover 214 million acres (only 13.3 million of which are managed by the Forest Service) or about 40 percent of the land area in the 13 Southern States. Although this equals about 30 percent of all forest land in the United States, southern forests provide more than 60 percent of the total timber harvested nationally. The leading producer of timber products in the world, the South is known as "the Nation's wood basket."

The forest products industry generates billions of dollars in economic benefits in the South and provides jobs for tens of thousands of residents. In addition, nontimber forest products such as landscaping stock, edible plants, and medicinal herbs contribute millions of dollars annually to the South's economy. But the benefits of southern forests go far beyond economics.

Forests are important and valuable ecosystems, providing a wide range of goods and services. They purify water, filtering about 60 percent of the region's drinking water. It is to the forests of the South that the region's expanding human population goes for recreational activities that range from hunting and fishing to hiking and bird watching. Southern forests also harbor a rich diversity of plants and animals, including species found nowhere else in the world.

As climate change progresses, the South's natural and human systems will have to adapt in order to survive, with some species changing their locations and habitats. Forest ecosystems already under stress from changing weather patterns will be primary refuge habitats for

The leading producer of timber products in the world, the South is known as "the Nation's wood basket." (Photo courtesy of the South Carolina Forestry Commission)

animal and plant species, many of which are already threatened or endangered. Forests also play a primary role in mitigating some of the effects of climate change; as trees take up and sequester carbon, they reduce the amount of carbon dioxide released into the atmosphere.

Land managers asked to address the challenges of climate change—most immediately extreme weather events and climate variability—will have questions about the specific effects of climate change and which practices will help them to meet their management goals. SRS is committed to answering questions about climate change effects, and to developing science-based tools that help forest managers, planners, and many others make informed decisions about adaptation.

The SRS Global Change Research Strategy will help identify best management practices for southern forests and their associated watersheds to sustain ecosystem health and services ("adaptation"), while also maintaining and/or increasing carbon sequestration ("mitigation"), under changing climate conditions. The underlying goal of the SRS strategy is to increase understanding of regional forest ecosystems leading to management that sustains and provides ecosystem services for future generations.

Forest ecosystems already under stress from changing weather patterns will be primary refuge habitats for animal and plant species, many of them already threatened or endangered. (Photo courtesy of the USDA Forest Service)

This document reviews SRS research program strategies in relation to climate change, including those focused on wildfire, invasive species, insects, and biomass and biofuels. The research described in this document is designed to support a full range of stakeholders including NFS managers and planners; other Federal, State, and local land managers; private landowners; industry and investment management organizations; and others. The intended audience for this overview is land managers and administrators at every governance level, global change scientists and administrators, and the interested public.

Basis

It is increasingly apparent that the climate of the Earth is changing and that it will continue to change well into the next century. Observed effects include:

- Warming in the lower atmosphere (troposphere) coupled with cooling in the upper atmosphere (stratosphere);
- Warming more at the poles than at the equator;
- Warming more over land than over the sea;
- Warming more in winter than in summer;
- Warming more at night than in daytime;
- Increasing intensity of the hydrological cycle, including more rain in high latitudes and less in the subtropics; and
- Increasing climate variability producing more large storms and longer, more intense droughts.

In addition to changes manifested globally, the Southern United States is predicted to experience regional and localized effects from climate change, including:

- Changes in the patterns, frequency, and intensity of weather-related disturbances including hurricanes, ice storms, droughts, and floods that may interact synergistically with other threats to forest health such as insects, diseases, invasive species, and wildfire—resulting in rapid change in forest condition and type;
- Increases in precipitation amounts in the region coupled with more intense downpours and a greater proportion of region affected by prolonged drought;
- Even under wetter future climate projections, increases in temperatures which will contribute to higher rates of evaporation, lower water yield from forests, and corresponding water stress to both ecosystems and people;
- Increases in temperatures and drying that will shift species and the ecosystems they compose in unpredictable ways, often favoring invasive species, both native and nonnative; and
- A warmer and drier climate that increases the risk of wildfire and constrains fuels management, leading to shifts toward more fire-adapted vegetation and loss of rare habitats.

The South already experiences warmer winters and drier summers, with coastal areas facing rises in sea levels and tropical storms of increasing intensity. Forest Service scientists predict that southern forests will continue to experience more variability in weather leading to more frequent and intense drought, floods, and heat waves.

Ecological effects will be heightened by interactions among continuing disturbances from wildfire, land use change, air pollution, and invasive species. Because there is such a wide variation in ecosystems across the South—from the Southern Appalachian Mountains to the Gulf Coastal Plain and the Highlands of Arkansas—suggestions for management in response to global change will have to be tailored to the local level. This is especially true when recommending activities to increase carbon sequestration by forest management and when considering the use of woody biomass for energy production.

Southern land managers have conveyed a sense of urgency and a need for real-time information as they face a host of climate-change-related decisions. As SRS research moves forward, the experience of managers is increasingly incorporated into a shared learning environment where researchers and managers test new adaptation strategies and meet either virtually or face-to-face to talk about successes and failures across landscapes, regions, and

agencies. Land managers have reported a variety of research needs, which can be divided into four general categories:

- A better understanding of the basic concepts associated with climate change relevant to land management (e.g., vocabulary, ecosystem responses);
- Mechanisms for integrating climate change into multiple-use management (e.g., balancing stocking densities with other ecosystem services, climate effects on fire);
- Tools to implement climate change strategies into the management of specific forests (e.g., local future climate scenarios, vegetation projection models, vulnerabilities and risk predictions, implementation of land and resource management plans); and
- Increased interagency cooperation and outreach to citizens and other stakeholders, especially to socially vulnerable communities (e.g., adjacent landscape issues, stakeholder input to decisions and actions).

Approach

Forests play an intrinsic role in mitigating and adapting to the effects of climate change. For SRS, mitigation involves both reducing our operational footprint and focusing research efforts on:

- A more complete understanding of carbon sequestration in living trees;
- Increasing the storage of carbon in wood products; and
- Exploring options for using renewable wood-based energy to reduce fossil fuel consumption.

Adaptation efforts focus on:

- Determining the vulnerabilities of ecosystems in a range of future scenarios;
- Examining the possible scenarios of interaction among ecological, economic, and social systems in relation to climate change scenarios;
- Exploring management options for sustaining ecosystem function and minimizing the loss of ecosystem services;
- Applying approaches based on matrices of risk, vulnerability, and resilience; and
- Developing decision-support tools to help managers plan and implement long-term adaptation-based actions.

Research is aimed at developing adaptation and mitigation approaches to ensure that southern forests have the capacity to maintain health, productivity, and diversity while meeting carbon sequestration needs. To attain these goals it is important to understand that in many cases adaptation and mitigation efforts will be integrated into a single approach or practice. The SRS global change strategy contains four integrated elements aimed at enhancing the management of southern forests under changing climate:

1. **Research to Enhance Ecosystem Sustainability (Adaptation)** focuses on research that will advance management options to enhance ecosystem health and sustainability; ensure the maintenance of ecosystem services such as water, wildlife, biodiversity, recreation, and forest products; and reduce losses of ecosystem function from climate-altered disturbances such as wildfire, insects, and invasive species.
2. **Research to Increase Carbon Sequestration (Mitigation)** focuses on research that will assist managers in enhancing carbon sequestration through actions designed to increase forest growth rates and area of forested lands; enhancing biomass extraction and utilization research; and understanding long-term carbon storage pools.
3. **Research to Provide Decision Support** integrates the first two elements by developing decision-support tools and approaches for land managers, policymakers, and planners.
4. **Shared Research Needs: Infrastructure, Scientific Collaboration, and Science Delivery** focuses on the infrastructure and collaboration needed to generate new knowledge and applications in adaptation, mitigation, decision support, and science delivery.

Research to Enhance Ecosystem Sustainability (Adaptation)

The changes predicted over the next century will be rapid in some areas of the South. The Atlantic Coastal Plain is particularly vulnerable to the effects of sea level rise. (Photo courtesy of the USDA Forest Service)

The rich freshwater aquatic communities of the Southeast are already showing affects from changing weather patterns. (Photo courtesy of the USDA Forest Service)

Climate Change and Ecosystem Sustainability

Forest plant and animal species—terrestrial and aquatic—are adapted to local climates, some to more specialized conditions than others. Scientific study has shown that when climate changed abruptly in the past, species responded by adapting over long periods of time through genetic selection or more immediately by migrating to more favorable areas. The changes predicted over the next century will be rapid in some areas of the South (such as the Coastal Plain areas, which will be affected by sea level rise); adaptation is complicated by other stresses and by a landscape fragmented by human development.

The capacity of the forests sheltering these species to remain healthy will be further challenged by the predicted effects of climate change. Species, varieties and whole ecosystems may become progressively more stressed, and current refuges for threatened and endangered species may disappear. Developing adaptation strategies for southern forests will involve evaluating the region's range of ecosystems in terms of risk, vulnerability, and resilience and identifying flexible suites of adaptation options.

Current Research Goals

Anticipating future climate conditions involves more than simulating increases in temperatures and variability in precipitation. Scientists must seek to understand the "legacy effects" of past alterations of natural systems; future drivers of change (e.g., population growth and land use change); ecosystem responses to climate change; and all possible interactions among these. Some changes will limit the conditions for regeneration of many desirable species. Native and nonnative species will invade new habitats or experience altered competitive relations in their local communities. Changing conditions will cause effects at different rates and over a range of scales, complicating strategies for responding. Managers need adaptive approaches that focus on restoring resilience and facilitating adaptation where needed. By emphasizing ecological function, forest managers can plan for future conditions that incorporate novel ecosystems, or intervene to protect high-value plant and/or animal communities or move them to new locations.

The greatest and most immediate effects of climatic variability and change on ecosystems will likely occur indirectly or in concert with other stressors. For example, increased temperature will be coupled with various interacting stresses, including multiyear droughts, insect attacks, and wildfire, also enhanced by warming. Ozone and other pollutants—already problematic in extensive areas in the South—in combination with climate stress are likely to decrease forest productivity and increase the potential threats to forest health and ecosystem functionality.

Most projected climate change rates are approximately an order of magnitude more rapid than measured past rates of migration by tree species. Therefore, natural revegetation by local populations that also include climatically appropriate individuals will become very uncertain within a few decades. In addition, if projected rates of accelerated climate change are realized, land and resource managers engaged in reforestation, afforestation, and/or gene conservation will no longer have reliable guidelines for identifying which

Continued research is needed to improve the understanding of how climate change will impact the watershed systems of the South. (Photo courtesy of the USDA Forest Service)

seed sources to plant and where to plant them. This threat exists because present guidelines for predicting adaptation to climate in forest tree species are based on geographic variables that act as surrogates for climate.

Research Needs

Research to support adaptation on southern forests:

- Improve the understanding of potential climate change impacts on southern watershed systems and explore possible management actions to reduce impacts.
- Increase understanding of terrestrial and aquatic populations and communities of different ecosystems and how they will be impacted by climate change.
- Continue to quantify the effects of elevated carbon dioxide on forest productivity and water and nutrient cycles.
- Increase the capacity to measure in real-time the flow of carbon dioxide and other gases above the forest canopy to detect variations in nutrient gases in relation to climate change.
- Develop scenarios that describe interactions among multiple stressors under different projections of climate change effects.
- Enhance understanding of the interactions among climate change effects and climate-mediated disturbances such as wildfire, insect and disease infestations, and the spread of nonnative invasive species.
- Develop scenarios to explore the interactions among climate change, forest ecosystem services, demographic and social changes, and economic factors such as timber and bioenergy markets.
- Increase understanding of social impacts from and community responses to climate change, especially for socially vulnerable communities.
- Increase the adaptive capacity of management systems to explore strategies to increase the resilience of ecosystems and ecosystem services such as water supplies, aquatic and terrestrial habitat, recreation, and forest products.
- Provide targeted information on the effects of land use change in relation to projected climate change effects.
- Refine and develop new strategies to enhance forest productivity and ecosystem services.
- Develop and test knowledge support systems to help land managers make decisions on both local and landscape levels.
- Develop systems to monitor forest stress in real-time to support proactively managing forests in the face of impending climate change.
- Investigate how land cover changes affect surface climate and hydrology in the South and the role afforestation could play in partially offsetting warming effects from increased atmospheric carbon dioxide.

Near-Term Research Products

Near-term research products, defined as those attainable over the next decade, involve enhancing ecosystem resilience under increasing climate stress and synthesizing existing understanding from original research on the potential vulnerabilities and ecosystem responses to a changing climate with management options for application by land managers. Specifically, SRS will:

- Conduct integrated assessments to determine potential impacts on water quality and quantity in relation to population and land use change; assess vulnerabilities across different spatial scales including the identification of potential "hotspots;" develop and assess the potential of various management strategies; and uncover potential unintended consequences of mitigation and adaptation actions.
- Combine literature and case studies to provide an overview of potential effects on representative species or suites of aquatic and terrestrial wildlife species in the five ecoregions of the South; provide models and forecast potential shifts in the distribution of select species; and develop management guidelines for wildlife conservation in a changing climate.
- Investigate how changing climate conditions affect North American forest communities by forecasting future locations that provide suitable habitat for at least 100 North American tree species.
- Enhance modeling for effects on threatened, endangered, and sensitive (TES) species in relation to invasive nonnative species by using existing life history information, demographic data, and overlay maps to help predict where target TES species could be expected to persist or die out.
- Refine and combine climate and hydrologic models to provide a better understanding of potential climate effects on freshwater fish and water quality in the region and to develop conservation strategies.
- Incorporate eddy flux and other data into existing hydrologic models to increase model accuracy and responsiveness to climate change.
- Project the likely effects of climate change on the spread of nonnative invasive plant species using remote sensing, data mapping, modeling, and knowledge of physical characteristics, distribution patterns, and invasion rates, and develop strategies for control and eradication.
- Enhance the quality of models addressing the interaction of wildfire and climate change, especially when combined with heightened hurricane activity in the southern Coastal Plain.
- Build on Southern Forest Futures Project (SFFP) forecasts of climate change impacts on ecosystem services such as water and wildlife coupled with population and land use change.
- On experimental forests, use long-term studies combined with new experiments to develop and test strategies for conserving and enhancing forest resources (e.g., restoring longleaf pine forests, which have been shown to be more hurricane and insect resistant) to their former range.
- Use pilot projects to develop and test strategies for conserving and enhancing resource (e.g., soil, water, habitat, biodiversity, vegetation) health in face of climate change effects such as sea level rise.
- Improve spatial resolution of future climate projections to guide management through dynamic downscaling of regional climate models.
- Improve methods for region-level assessment of vulnerability to climate change in order to identify robust adaptation strategies.
- Improve models of wind effects on forests to better predict risk of damage from extreme weather events such as coastal hurricanes.
- Develop and test silvicultural strategies to reduce effects of extreme wind events.

Research to Increase Carbon Sequestration (Mitigation)

Trees store carbon in trunks, branches, leaves and roots—keeping it out of the atmosphere where it contributes to global warming. (Photo courtesy of the USDA Forest Service)

Free-air carbon dioxide enrichment (FACE) sites are used to study how forests store and cycle carbon under changing climate conditions. (Photo courtesy of the USDA Forest Service)

Climate Change and Carbon Sequestration

Forests store large amounts of atmospheric carbon, which is taken up during the process of photosynthesis and sequestered in plant biomass (tree trunks, branches, foliage, and roots), thus acting to mitigate climate change. Elevated atmospheric carbon dioxide has prompted forest managers to consider using increased forest carbon sequestration as one way to partially offset gross carbon emissions. Carbon sequestration rates vary by tree species, soil type, regional climate, topography, and management practice.

Practices that aim to reduce carbon losses and increase sequestration are compatible with other forest management objectives, including soil stability, water and air quality, and wildlife habitat. For example, tree planting that restores forest cover may not only sequester carbon but also improve habitat for wildlife. Reducing soil erosion through tree planting or soil conservation measures can sequester carbon and improve water quality by reducing runoff. On the other hand, forests are subject to disturbances such as storms, fire, or harvest that can suddenly or gradually release the carbon back to the atmosphere.

Mitigation research is focused on developing ways to increase the amount of carbon dioxide removed from the atmosphere and stored long term in forests or wood products. Longer term storage helps to mitigate the effects of global change produced by rising levels of greenhouse gases—including carbon dioxide—produced by human uses. Mitigation research also focuses on the use of woody biomass as one part of a portfolio of alternative renewable energy sources to fossil fuels. Looking at how efficiently and sustainably woody biomass can be grown, transported, and burned is an increasing focus of mitigation research.

When hurricanes and other major disturbances kill trees, carbon is suddenly released back into the atmosphere. (Photo courtesy of the USDA Forest Service)

Current Research Goals

SRS carbon sequestration research focuses on understanding more fully the movement of carbon through trees and soil, especially on understanding belowground processes and differences in carbon sequestration in relation to tree age and stand dynamics. Research also focuses on the carbon storage capacity of forest products and the potential of woody biomass as an alternative energy source. Carbon sequestration research includes:

- Developing new knowledge about carbon movement and storage in tree roots and soil.
- Exploring the carbon storage capacity of new or reengineered forest products, including woody biomass for energy uses.
- Creating and/or testing new equipment that minimizes the costs of transporting woody biomass; analyzing processing of small-diameter wood and residues for energy use; testing equipment for the conversion of woody biomass to energy products such as bio-oil.
- Continuing economic and social analyses on the potential impacts of wood-based energy on markets and forest sustainability in the South.
- Developing innovative improvements to monitoring systems at multiple scales to better integrate data from forest inventories, remote sensing, and specialized sites on Forest Service experimental forests.
- Identifying effects of planting nonnative species such as eucalyptus for bioenergy on wildfire risk and invasiveness.

Research Needs

Further research is needed to refine the data about carbon sequestration in forest ecosystems and wood products that are used in predictive modeling; more specifically:

- Synthesize what is currently known about carbon sequestration in forest ecosystems and wood products; identify major gaps in knowledge for targeted research.
- Determine how different tree species and forests respond to rising levels of atmospheric carbon dioxide, and the effects of those adaptations on other processes.
- Improve the understanding of factors controlling land use change, the quantification of past trends, and the ability to make projections and estimates of long-term impacts on carbon stocks.
- Investigate and quantify soil carbon and the effects of management, climate, and land use change on soil carbon levels.
- Continue to develop technology to accurately measure carbon respiration from soil as well as belowground carbon cycling.

SRS develops innovative technology and methods to accurately measure how carbon moves through soil and tree roots. (Photo courtesy of the USDA Forest Service)

- Refine regional and State-level estimates and projections of woody biomass supply in relation to current and projected bioenergy demand.
- Improve technical, ecological, economic, and carbon performance of forest operations to produce woody biomass for energy feedstocks and other products.
- Use life-cycle analysis to improve forest management and the use of wood for bioenergy and other bioproducts.
- Develop market approaches that integrate woody biomass production with sustainable forest management.
- Evaluate private landowner and public receptivity to alternative carbon management practices, policies, and incentives.

The South is home to many distinct ecosystems, such as longleaf pine forests. Little is currently known about how different tree species and forests respond to rising levels of atmospheric carbon. (Photo courtesy of the USDA Forest Service)

Near-Term Research Products

Products incorporating carbon sequestration research will be used to inform policymakers, land managers, and citizens about the many issues involved in this strategy. Specifically, SRS research will:

- Synthesize findings from long-term experiments in carbon dioxide-enriched experiments to support the models used to project carbon sequestration potential of southern forests, including findings on the relation between soil nutrition and carbon sequestration.
- Conduct carbon, water, and energy-balance monitoring based on a network of eddy flux sites located in forest cover types representative of those common to the southern region.
- Build on the SFFP forecasts of climate change impacts on ecosystem services such as water and wildlife coupled with population and land use change.
- Conduct analyses of supply and demand for biomass energy feedstock and potential effects on traditional forest products markets and private landowner decisionmaking processes.
- On a range of ownerships, evaluate changes in carbon storage in mature forests (more than 50 years old), especially those that have escaped silvicultural interventions.
- With university, private industry and Federal Agency partners, develop new mechanized systems for harvesting in pine plantations planted for bioenergy.
- Evaluate machinery and systems used to harvest, process and haul biomass for energy, providing landowners with realistic costs when planning to grow bioenergy feedstocks.
- Evaluate the thermochemical characteristics of commercial and noncommercial woody biomass to assess potential for bioenergy and biofuels use.
- Create a method to estimate carbon biomass lost to disturbances such as hurricanes and insects.
- Compare total emissions from infrequent wildfires with those of periodic prescribed burning, including effects of seasonality on the generation of ozone precursors.

Research to Provide Decision Support

SRS research focuses on creating and improving tools and models managers, planners, and policymakers can use to predict future trends in forest ecosystem health. (Photo courtesy of the USDA Forest Service)

Creating opportunities for scientists and forest managers to interact is fundamental to all SRS efforts. (Photo courtesy of the USDA Forest Service)

Decision Support for Climate Change

Informing stakeholders about the effects of climate change on future resource management and policy is just as critical as the research behind it. Advancing interaction between scientists and forest managers is fundamental to all SRS efforts. This research element seeks to improve the conveyance of scientific information and the deliberate processes used to integrate science into all levels of decisionmaking, from planning to project implementation and monitoring.

Research activities will involve the full range of SRS research, from genetics to silviculture to economics and social science, as well as the involvement of communication and outreach professionals at all levels.

Because climate change science is inherently complex and interdisciplinary, scientists need routine and repeated interactions with resource managers to ensure that research products are relevant to various management applications and are applied in an appropriate manner. This necessity implies early and frequent communication with managers to ensure that scientists understand what information is needed for planning and operations at different spatial scales, and that managers are informed about what products are available and how best to use them. Collaboration is critical for implementing mitigation activities, which include the stream of activities related to carbon accounting and the use of biomass. Collaboration is also critical for implementing adaptation strategies from the planning stage to operational actions, including the monitoring that informs the adaptive management process.

Current Research Goals

In the area of decision support, research efforts currently focus on synthesis, assessment, and the development of models and tools designed for use by land managers at all levels—Federal, State, local, and private landowner. Decision-support research allows SRS to integrate

The use of prescribed fire to improve conditions in the forests of the South becomes problematic as population increases and development spreads. SRS provides tools for communities to address this and other important land management issues. Photo courtesy of the USDA Forest Service)

models developed by Station scientists with climate change data to develop scenarios and technology-based tools designed to help planners and managers ensure the sustainability of ecosystem services such as drinking water supply, terrestrial and aquatic habitat, and recreation. Decision-support research involves:

- Developing regional syntheses, integrated assessments, and tools to support decisionmaking.
- Integrating climate change projections with projections of population, land use, forest products markets including bioenergy, and other factors to produce future scenarios for the South.
- Integrating present forest plans with scientific literature to provide planning tools for management of national and private forest lands.
- Developing real-time monitoring tools managers can use to quickly identify forest disturbance and damage remotely.
- Integrating spatial and economic information layers to create a relational database for geographic-based economic cost assessment for woody and agricultural residue biomass collection or processing demand centers.
- Developing carbon accounting tools managers can use to understand the carbon footprint of management activities.
- Supporting and conducting continuing education workshops, Webinars, and other programs to familiarize land managers and policymakers with decision-support tools and models.

Research Needs

SRS research is focused on creating and improving decision-support tools and models that managers, planners, and policymakers can use to predict future trends in both human actions and forest ecosystem health at multiple levels of time and space. These decision-support tools are augmented by scientifically based synthesis and future scenarios. New or continued research is needed to:

- Create effective processes for stakeholders with disparate goals and views to integrate information from multiple analytical tools into a decisionmaking process.
- Develop decision-support tools that allow fine-scale monitoring in forest ecosystems in real-time to help managers form and evaluate response strategies.
- Integrate into models climate and other stress agents and the responses of biotic and physical components of forest ecosystems.
- Determine important tipping points, phase transitions, and emergent thresholds under climate change and include them in the models used to investigate climate change.
- Continue to develop economic models and incorporate them into synthesis products that simulate what will happen under different scenarios of climate change. Include considerations of carbon sequestration, ecosystem resilience, ecosystem services, forest products, and biofuels.
- In partnership with land managers, identify and develop decision-support tools that effectively facilitate management decisions under changing climate conditions.

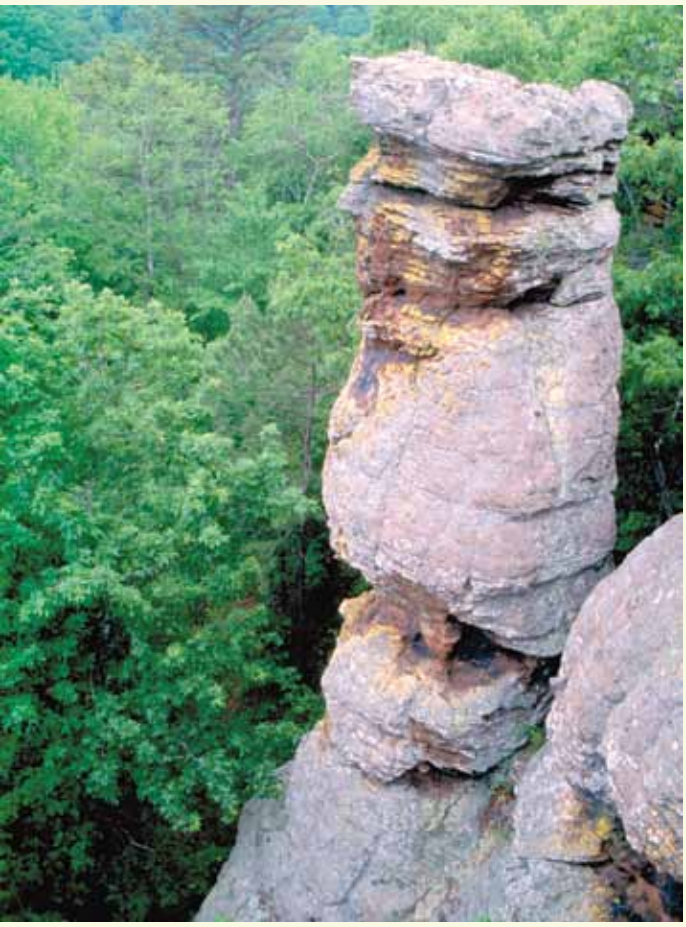
Near-Term Research Products

Decision-support products expected during the next few years involve creating and modifying important resource management models to integrate climate change. Specifically, SRS research will:

- Develop a stress monitoring and decision-support system across multiple sites in the Eastern United States that provides remote data capture of climate-related forest stress and provides land managers a tool to monitor and assess the severity of climate-related stress.
- Develop water supply and demand scenarios for planners at the regional and national levels tied to several different climate change models and to population and land use change projections.
- With the NFS, refine the Template for Assessing Climate Change Impacts and Management Options (TACCIMO)—a Web-based decision-support tool that combines the best available science with current management options to enable planners and managers to ensure sustainable forest resources that meet multiple demands.
- In a cooperative effort with numerous outside partners, develop Climate Change Adaptation and Mitigation Management Options (CCAMMO)—a reference publication synthesizing scientific studies and data and designed to describe land management options in relation to climate change effects around a suite of ecosystem services.
- Provide full access to the SFFP, which will provide a valuable resource for land management planners to structure decisions that account for integrated effects of economic, ecological, and demographic change at the subregional scale.
- Continue to refine the Comparative Risk Assessment Framework and Tools (CRAFT)—a planning and decision-support framework that offers a structured approach for stakeholders to determine objectives and calculate risks and tradeoffs associated with different management objectives.
- Develop prescribed burning decision-support tools that provide information on prescribed burning windows, changes in fuel loading, and wildfire potential under various climate change scenarios in the South.

Shared Research Needs: Infrastructure, Scientific Collaboration, and Science Delivery

SRS and the U.S. Geological Survey work together to integrate models on aquatic systems and to advance landscape-level science. (Photo courtesy of the USDA Forest Service)



(Photo courtesy of the USDA Forest Service)

Corporate Strategies for Addressing Climate Change

The research needed to generate new knowledge and applications in adaptation, mitigation, and decision-support research has been outlined separately in the sections above. It should be apparent that many research activities incorporate all three areas, and that providing the infrastructure, personnel, and technology transfer activities to sustain all three requires a coordinated effort from SRS. The following section describes, in general, the infrastructure, scientific collaboration, and science delivery needed to support the research areas.

Infrastructure

Infrastructure and facilities essential to the success of SRS research include access to remote sensing and other monitoring capabilities and a continued strong base in forest inventory and analysis (FIA). Remote sensing and other data collection capabilities—including eddy flux and real-time monitoring—are necessary to provide the data for modeling and for refining the models for carbon sequestration, ecosystem vulnerability and resilience, bioenergy supply and generation, and decision support that will guide future management decisions. All SRS research efforts rely on the data generated by the FIA Program to determine vegetation changes in relation to a wide range of disturbances including climate change.

Eddy covariance towers are used by SRS and partners to measure the flow of carbon dioxide and other gases in the forest canopy. (Photo courtesy of the USDA Forest Service)

In order to better address the needs of land managers in the South, SRS needs to continue building towards a comprehensive simulation modeling capacity that integrates state-of-the-art models of air, water, forests, species, economics, and human population and land use changes. SRS must continue to upgrade the capacity to provide the regional-scale analyses, projections, and scenarios needed for assessments related to climate change. Other actions SRS should take to enhance common facilities and assets include the following:

- Coordinate Data. Continue to enhance the collection, integration, and formatting of data for analysis and modeling to increase and refine understanding of the effects of climate change on southern forest ecosystems.
- Share Data. Continue to expand the types of disturbance-related data collected by FIA, and encourage analysis and use of the data by other entities.
- Support More Data Collection on Experimental Forests. The experimental forests administered by SRS cover the full extent of ecosystems in the region, and could be more fully utilized to collect climate-related data more intensely. Experimental forests are also repositories for the longest term onsite data collections by Station scientists. Many of these collections need to be reformatted to be fully used in modeling programs.
- Increase Geographic Information Systems support across research units.

Scientific Collaboration

The impacts of climate change span both spatial and disciplinary boundaries. Scientifically based approaches to climate change effects require the interaction of scientists and support staff from many disciplines and technical expertise backgrounds, and cannot be properly contained in any one SRS research unit or even the

Station itself. In the past few years alone, SRS has started significant collaborations with Federal, State, nonprofit, and private entities, but more can be done, including:

- In collaboration with the Forest Service Southern Region, the Southern Group of State Foresters, university partners, and others build on the set of future scenarios developed for southern forests over the next 50 years that link climate change with economics, population and land use changes, and other factors.
- Continue Web-based collaboration with the Forest Service Northern Research Station (NRS) and others to present monthly programs on current research on climate change at SRS and NRS.

A second important facet of science delivery will be the enhancement of relationships with organizations outside the Forest Service. SRS actively pursues opportunities to work with other scientific organizations, including:

- In collaboration with the U.S. Geological Survey (USGS), integrate models on aquatic systems in two high-elevation watersheds in the Southeastern United States to examine how projected climate changes, specifically in air and water temperature, will affect aquatic ecosystems.
- With USGS Patuxent Research Center, continue a pilot project to establish a pollinator-monitoring network across 12 experimental forests and ranges.
- Continue efforts with the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center to develop common research programs based on weather data and forest-related research.
- Continue to collaborate with NOAA's National Climatic Data Center on projects that enhance public understanding of climate change at multiple scales.
- With the National Aeronautics and Space Administration and the Oak Ridge National Laboratory, create a national early warning system to monitor real-time threats to forests that will help track landscape-level alterations as climate continues to change.
- Coordinate with the Department of the Interior Climate Science Centers and Landscape Conservation Cooperatives to obtain needed information resources and share products with a broad external customer base.
- Continue partnerships with the U.S. Agency for International Development and other entities on climate-monitoring projects in western Africa and other international locations.

Science Delivery

Effective science delivery is an iterative process that involves understanding user audiences and their information needs, targeting scientific studies to meet those needs, developing research products for the range of audiences, and getting feedback to refine both study areas and products to better serve users.

SRS units and scientists have long engaged in partnerships with local private and industrial forest landowners. It is important that SRS continue to support these relationships and continue to build research-management partnerships at the Station level to ensure that climate change science is infused into management and planning. Activities to enhance SRS science delivery include:

- Expand the offerings of the Climate Change Resource Center, available online at http://www.fs.fed.us/ccrc/, to include science specific to the South.
- Develop partnerships among scientists, stakeholders, and communications experts to provide user-friendly information and access in a variety of formats.
- Expand the SRS suite of Web-based tools to quickly and efficiently share information with other scientists, foresters, decisionmakers, and other users in the public and private sectors.
- Continue to seek opportunities to engage in cooperative research highlighting Forest Service expertise with expertise of other Federal and State researchers.
- Ensure that research units and teams have access to science delivery personnel who are knowledgeable about SRS research, familiar with stakeholders, and able to contribute ideas about how best to convey particular research findings.

- Create interfaces and products where trained science communicators work with scientists to convey complex information and knowledge to managers, policymakers, and the public.
- Combine time-tested communications techniques such as printed and online journal articles, popular magazine articles, news releases, and videos with new and emerging technologies, including social media, to deliver valuable information and products to users.

Concluding Thoughts

Climate change impacts are already apparent in the forests of the South, where disturbance from weather events, pests and diseases, and wildfire is complicated by rising human population and rapid conversion of forested land to other uses. Southern forest ecosystems are already changing, as are their capacities to adapt to and mitigate climate change impacts.

The SRS Global Change Research Strategy outlines current research and future programs planned by the Station. Essential to all of these efforts are continued partnerships with land managers and decisionmakers, whose input will make it possible for SRS to develop a full range of products and tools that include:

- Accessible, user-friendly models, both qualitative and quantitative, that simulate, synthesize, and summarize climate change impacts in formats that are easy to navigate and adapt to localized needs.
- Training workshops, Webinars, and Web-based information to familiarize managers with how to run and optimize the tools and models developed by SRS scientists and technology experts.
- Outreach and technology transfer through existing and emerging networks to educate, inform, and elicit public comments and preferences on adaptation and mitigation strategies developed by SRS scientists and collaborators, e.g., through the public comment system for national forest plans.
- More effective use of the extension system, with SRS scientists and communication staff developing products directly tailored to land manager needs identified by agents of the USDA Cooperative State Research, Education, and Extension Service in the 13-State region served by the Station.

(Photo courtesy of the USDA Forest Service)

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

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