USDA

FOREST SERVICE
US
DEPARTMENT OF AGRICULTURE

Northern Research Station

CLIMATE CHANGE RESEARCH
FY 2010 BUSINESS REPORT

INTRODUCTION

The Northern Research Station of the USDA Forest Service is committed to making a difference by improving citizen's ability to cope with forest changes and thrive as climate change emerges as both a significant threat and opportunity. The U.S. Congress has made a good investment in recent years to address climate change impacts, adaptation, and mitigation. The Northern Research Station is increasing capacity for climate change research in staffing decisions and support for research infrastructure. At the same time, the Northern Research Station is meeting short-term needs for increasingly sophisticated information about sustaining forests in an uncertain future through adaptive management, and determining how forests may reduce the burden of greenhouse gases in the atmosphere resulting from fossil fuel emissions. This report documents recent products and outcomes from the climate change research program, the continuing commitment to excellence in science delivery and communications, and the exciting new work that has begun in response to increased interest and funding.

Michael T. Rains
Station Director

Northern Research Station

Big Falls
Kawishiwi
Cutfoot
Marcell
Pike Bay
Grand Rapids
Houghton
Dukes
Argonne
Harshaw
Rhinelander
St. Paul
Udell
Lower Peninsula
Coulee
Madison
East Lansing
Chicago
West Lafayette
Paoli
Columbia
Kaskaskia
Sinkin
Princeton
Delaware
Warren
Kane
Morgantown
Vinton Furnace
Fernow
Parsons
Newtown Square
Baltimore
Baltimore
Newark
Silas Little
New York City
Hamden/Ansonia
Amherst
Syracuse
Burlington
Bartlett
Hubbard Brook
Massabesic
Durham
Orono
Howland
Penobscot

○ Offices and Research Laboratories
◆ Experimental Forests

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BACKGROUND AND BUDGET SUMMARY

The Northern Research Station (NRS) climate change research program operates within the broad context of the U.S. Global Change Research Program and the Forest Service Strategic Framework for Climate Change. The Forest Service Strategic Framework includes actions in management, science, and technology transfer organized under seven key elements:

1. **Science**—Advance our understanding of the environmental, economic, and social implications of climate change and related adaptation and mitigation activities on forests and grasslands.

2. **Adaptation**—Enhance the capacity of forests and grasslands to adapt to the environmental stresses of climate change and to maintain ecosystem services.

3. **Mitigation**—Promote the management of forests and grasslands to reduce the buildup of greenhouse gases while sustaining the multiple benefits and services of these ecosystems.

4. **Policy**—Integrate climate change, as appropriate, into Forest Service policies, program guidance, and communications and put in place effective mechanisms to coordinate across and within Deputy Areas of the Forest Service.

5. **Sustainable Operations**—Reduce the environmental footprint of Forest Service operations and be a leading example of a green organization.

6. **Education**—Advance awareness and understanding regarding principles and methods for sustaining forests and grasslands, and sustainable resource consumption, in a changing climate.

7. **Alliances**—Establish, enhance, and retain strong alliances and partnerships with federal agencies, state and local governments, tribes, private landowners, non-governmental organizations, and international partners to provide sustainable forests and grasslands for present and future generations.

National and Forest Service Climate Change Strategy with Research Linkages
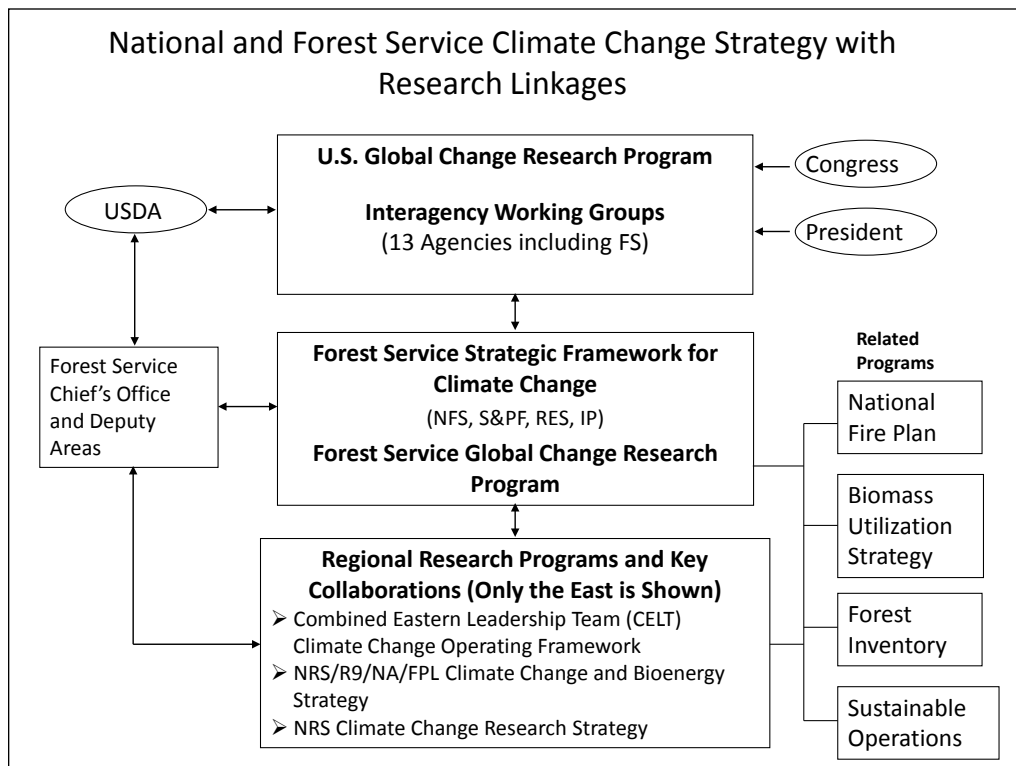
Table 1.—National Growth Opportunity Goal (dollars in millions)

	FY 2008	FY 2009	FY 2010	FY 2011[a]	FY 2012	Total
Science-based understanding (annual increase needed)	$4.5	$6.0	$10.5	$6.5	$6.5	$34.0
Science-based understanding (cumulative increase needed)	4.5	10.5	21.0	27.5	34.0	34.0
Actual appropriations (annual increase)	2.5	5.0	5.0	-3.5		
Actual appropriations (cumulative increase)	2.5	7.5	12.5	9.0		
Base program	19.4	19.4	19.4	19.4		
Total Program	**$21.9**	**$26.9**	**$31.9**	**$28.4**		

[a]President's budget

The Forest Service Global Change Research Program encompasses most of the elements of the Forest Service Strategic Framework:

1. **Research to Enhance Ecosystem Sustainability (Adaptation)**—Adaptation research will advance management options under a changing climate to enhance ecosystem health and sustainability, insure the flow of ecosystem services such as water, wildlife, biodiversity, recreation, forest and grassland products, and reduce losses of ecosystem function from climate-altered disturbances such as wildfire, insects and other invasive species.

2. **Research to Increase Carbon Sequestration (Mitigation)**—Mitigation research will lead to reduced atmospheric CO_2 concentration by increasing the amount of CO_2 removed from the atmosphere by U.S. forest and grassland ecosystems, including agroforested and urban forest ecosystems, and transferring biomass out of forests and into wood products.

3. **Research to Provide Decision Support**—Research will support policy, planning, and land management decisionmaking by translating the available scientific information into useable management and planning information, and developing decision-support tools.

4. **Shared Research Needs: Infrastructure, Scientific Collaboration, Technology Transfer**—Certain infrastructure, personnel, and technology transfer will be needed to sustain all three research elements, requiring a coordinated national effort within the Forest Service and with our partners in other agencies, universities, and the private sector.

In the East, NRS climate change research features close collaboration with the Southern Research Station, the National Forest System (Eastern Region), and Northeastern Area State and Private Forestry. This collaborative approach helps target climate change science actions to enhance management practices in shared landscapes of both public and private sectors. Climate change research at NRS is guided by a strategic plan, updated annually to reflect research status, funding, and program direction from Congress, U.S. Department of Agriculture, and the Forest Service National Office.

In 2008, the Forest Service devised a "growth opportunity" illustrating investments, actions, and outcomes. The science component of the "growth opportunity" calls for an additional $34.0 million above the historical base funding of $21.9 million (Table 1). If fully implemented, the NRS share of this increase would be $5.4 million, and the base research program would remain strong including continuation of the world-renowned Aspen-FACE experiment in Rhinelander, WI. From 2008 to 2010, Congress provided an additional $12.5 million for climate change research to the Forest Service (Table 1). The NRS share of this increase is $3.9 million (Table 2, page 16) through FY 2010, which includes funding for national projects managed by the NRS: carbon cycle science, climate change assessment, and economics. Additional detail about the NRS climate change research budget and its allocation to research program areas can be found in Appendix 1.

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[1]"Forest Research in Response to Climate Change: A Strategic Plan for the Northern Research Station" updated December 2010. The report is available by contacting Richard Birdsey, rbirdsey@fs.fed.us

Highlights from fiscal year 2009

The NRS has formally conducted climate change research since 1991, though much of the science base was begun a decade earlier under the "Acid Rain" research program. NRS is widely recognized for pioneering research to develop methods for estimating the greenhouse gas inventory of U.S. forests, for providing decision-support tools for analysis of climate change mitigation and adaptation, and for fundamental research on ecosystems and the carbon cycle. NRS also has established a strong science base and modeling capability to project and assess the future effects of climate change and other factors on the health and productivity of forests, and to develop methods for sustainable management of forest stands and larger landscapes. In this section, we highlight some of the accomplishments that were enhanced by funding increases through FY 2009. A more detailed review of the NRS climate change research accomplishments of the base program from 2005 through 2009 is presented in Appendix 2. Appendix 3 provides detailed information about each of the research projects and capacity-building investments made from the increased funding received through 2009.

The NRS Climate Tower Network

NRS maintains a network of climate research towers at several of the Station's Experimental Forests: Howland Research Forest, Maine; Bartlett Experimental Forest, New Hampshire; Silas Little Experimental Forest, New Jersey; Marcell Experimental Forest, Minnesota; and the Baltimore Long-term Ecological Research Site, Maryland.[2] NRS also restarted the climate tower at Willow Creek on the Chequamegon-Nicolet National Forest in northern Wisconsin after funding from the U.S. Department of Energy (DOE) ended.

Climate towers provide high-resolution monitoring of CO_2 exchange between the land and air, and also monitor meteorology, radiation, and water balance. Weather instruments were upgraded to the standards of NOAA so that meteorological observations would be consistent with state-of-the-art climate monitoring stations operated by other agencies. The towers are used in studies of fire weather and emissions, for analyzing the effects of management and natural disturbance on forests, and for closely monitoring changes in ecosystem processes in response to climate variability—an essential element of an "early warning" system for detecting climate impacts on forests.

Recent discoveries include: the most detailed analysis ever performed of the impacts of insect defoliation on ecosystem productivity during and after a 3-year gypsy moth outbreak in New Jersey; measurement of the effect of lengthening growing season on net annual carbon uptake in New Hampshire; and improved data about age-related changes in carbon cycling of dead wood in forests following disturbance events. This new information forms the basis for scientifically credible and effective policy and decisionmaking regarding climate change mitigation opportunities and implementation of programs to reduce emissions or increase greenhouse gas sequestration

Climate tower at Howland, Maine.

Annual Greenhouse Gas Inventory of U.S. Forests

The NRS Forest Inventory and Analysis (FIA) program conducts annual forest inventories and analyses across the 20-state region and four Plains States, and provides annual estimates of forest carbon stocks and changes in forest carbon stocks for the U.S. greenhouse gas inventory.

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[2]www.nrs.fs.fed.us/units/climate/focus/carbon_water_energy/

NRS scientists use the national FIA database to prepare the greenhouse gas inventory for forests and wood products, reported by the U.S. Environmental Protection Agency to the United Nations Framework Convention on Climate Change.[3] Recent findings continue to confirm that a large carbon sink in U.S. forests and wood products offsets about 12 percent of U.S. emissions of CO_2 from the use of fossil fuels. NRS has made significant and long-lasting contributions to the international and domestic protocols for measuring, monitoring, verifying, and reporting changes in carbon stocks for the forest sector. FIA data (including carbon estimates and methods) are easily accessible through the Internet and are widely used as a standard for monitoring and analysis of forest management and the carbon cycle. Methods developed to estimate forest and wood product carbon pools are widely adopted and have become the standard for U.S. analysis and reporting. The U.S. greenhouse gas inventory is the principal source of peer-reviewed, quantitative information about past and current trends in stocks of carbon in forests and wood products. Thus, the data are essential for formulating sound policies and programs for climate change management, and for monitoring the effectiveness of actions to reduce greenhouse gases under both domestic and international responses.


FIA field crew member observing tree crown. From www.fia.fs.fed.us/library/briefings-summaries-overviews/

Decision-support Tools for Managing Forest Carbon Stocks

Management of forest carbon involves development of silvicultural practices and management systems for increasing carbon sequestration and reducing or avoiding emissions; analyses to support greenhouse gas policies and programs; and development of accounting rules and guidelines to support emerging carbon registries and markets. NRS carbon management research and science delivery is geared to support the land management information needs of both public and private landowners. Widely used decision-support tools[4] facilitate participation in carbon markets and registries, and support "good practice" for sustainable forest management. Here are brief descriptions of three of the most popular tools:

- The Carbon OnLine Estimator (COLE) is a Web-based tool for forest carbon analysis that generates carbon estimates based on FIA data for any part of the continental United States. Reports provide ecosystem carbon data for evaluation and reporting to many of the emerging carbon markets and registries using accepted accounting rules and guidelines.
- The Forest Vegetation Simulator (FVS) is used by most National Forests to project the consequences of management activities. NRS worked with the Rocky Mountain Research Station to add a module to estimate carbon stocks of inventoried and simulated stands, enabling managers to compare the carbon consequences of management alternatives.
- The CarbonPlus Calculator uses local data to help residences and businesses estimate their carbon emissions and identify opportunities to reduce those emissions. The calculator is developed in partnership with cities and is currently operating in Philadelphia, New York, Baltimore, and Boston. Addition of other cities is an easy step requiring only an inquiry from local organizations.

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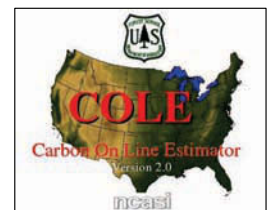
[3]nrs.fs.fed.us/clean_air_water/monitoring_carbon/nghgi/
[4]www.nrs.fs.fed.us/carbon/tools/

The participants of the National Advanced Silviculture Program brainstormed management approaches for creating forests that can adapt to climate change.

The NRS is also developing a full life-cycle carbon calculator for forest landowners and policy makers in the Northeast, and testing this calculator by conducting a life-cycle assessment (LCA) of the carbon sequestration performance of three large commercial forest landscapes and two large public forest landscapes in Maine. The Forest Carbon LCA Calculator will allow landowners to estimate their full life-cycle carbon sequestration capacity using their own forest growth/stocking data and forest product mix. This research is coordinated with related research at the Pacific Northwest Research Station and the Forest Products Laboratory. The NRS is adding carbon reporting functions to two decision-support systems widely used in the Northeast, NED, and SILVAH. This project will provide multiple benefits, including updated versions of SILVAH and NED, that will allow forest managers to examine the carbon consequences of management along side other management objectives, a carbon tools selection guide to help users select the best tool for their analysis needs, and training materials on the new carbon reporting functions.

Forest Management for an Uncertain Climate Future: Tools and Training

NRS helps land managers address the need for forest management to adapt to a changing climate in the Northeastern and North Central regions of the United States using several integrated approaches:

- Provide training to forestry professionals on climate and carbon monitoring technology and on the ecological impacts of climate change
- Incorporate current understanding of species and forest responses to climate change into silvicultural strategies that meet management objectives while encouraging adaptation to changing climate conditions
- Develop and provide decision support tools to guide forest management planning under climate change
- Integrate climate change adaptation strategies into Forest Service silvicultural education and planning

NRS sponsored numerous workshops and training sessions around the region to enhance awareness of the issues and promote inclusion of climate change-related factors in forest-planning decisions. Services are provided by several NRS groups: the Northern Institute of Applied Carbon Science (NIACS);[5] the Northern Science, Technology, and Applied Results Program (NorthSTAR),[6] and the Research Unit Climate, Fire, and Carbon Cycle Sciences.[7]

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[5]www.nrs.fs.fed.us/niacs/

[6]www.nrs.fs.fed.us/units/northstar/
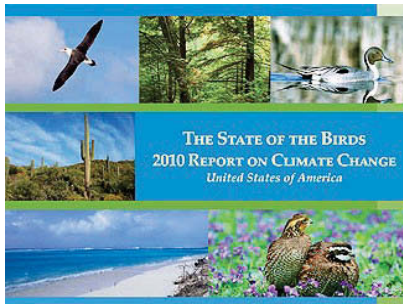
[7]www.nrs.fs.fed.us/units/climate/

Management Strategies for a Sustainable Future

NRS initiated a partnership with Princeton University in New Jersey with a mission to provide strategic decision support for managers and policy makers that will sustain U.S. forests under a changing climate. This partnership features development of advanced climate-sensitive forest dynamics models that will assist land managers in implementing landscape-scale strategic plans for carbon management under a changing climate in North America, and improvements to the land-atmosphere-ocean model system of the Geophysical Fluid Dynamics Laboratory (GFDL; a NOAA facility at Princeton) to support development of climate change policy at national and international levels. Research and strategic analysis with Princeton University and NOAA bridges the gap between global climate policy and regional land management with the most advanced climate and ecosystem models being applied at the Chequamegon-Nicolet National Forest in Northern Wisconsin as part of the "Model Forest" project described on page 8.

Climate Change Impacts on Trees and Wildlife

NRS scientists have developed climate change tree and bird atlases[8] to examine current distributions and model future climate habitats for 134 tree species and 150 bird species. The climate change atlases show potential tree and bird habitat responses to several global climate models and emission scenarios. The atlases are widely used in regional assessments of the impacts of climate change and strategic analyses of adaptation needs and opportunities. In addition to these atlases, NRS scientists are monitoring changes in distributions of key species as affected by climate change and other factors such as land-use change. For example, analysis of FIA data have revealed that distributions of tree seedlings for many species are shifting northward compared with distributions of mature trees. Analyses of long-term bird survey data show low-elevation birds are moving upslope, but montane spruce-fir species have actually extended their ranges downward. An NRS scientist represented the U.S. Forest Service on the State of the Birds Science Committee. The committee produced the report, *The State of the Birds: 2010 Report on Climate Change*, published in March 2010, that shows climate changes will have an increasingly disruptive effect on bird species in all habitats, with oceanic and Hawaiian birds in greatest peril.[9] The report indicates that the way lands are managed can mitigate climate change and help birds adapt to changing conditions. Long-term studies and models indicate that climate change effects on stream flow and temperature imperil trout populations throughout the Appalachian Mountains. Studies have also documented effect of climate variability on sensitive habitats such as the ephemeral forest pools that are breeding areas for salamander and frogs. As managers begin to develop strategies for adapting to and mitigating climate change impacts, they require data, analyses, and simulation tools that allow them to translate global climate model projections to reasonable local projections and to assess how these changes are likely to affect the habitat and species that are the targets of management actions.

Kirtland's Warbler. Photo by Ron Austing, USDA Find-a-photo.

[8]www.nrs.fs.fed.us/atlas/

[9]The report is the product of a collaborative effort as part of the U.S. North American Bird Conservation Initiative, between Federal and State wildlife agencies, and scientific and conservation organizations including partners from the American Bird Conservancy, Association of Fish and Wildlife Agencies, Cornell Lab of Ornithology, Klamath Bird Observatory, National Audubon Society, The National Fish and Wildlife Foundation, The Nature Conservancy, U.S. Forest Service, U.S. Fish and Wildlife Service, and the U.S. Geological Survey. See http://www.stateofthebirds.org/

The Chequamegon-Nicolet Model Forest: Helping Forest Managers Adapt through Knowledge Transfer

NRS Scientists develop the scientific knowledge needed for adaptation, targeting landscape-scale analysis of effects of climate change, climate variability, and air pollution on species and ecosystems. A project begun in FY 2008 called "Forest Management for an Uncertain Climate Future," produced nine seminars and workshops to educate forest managers about climate change and help them begin planning for climate change adaptation. Following this in 2009, NRS initiated a project with the Eastern Region of the National Forest System known as "The Chequamegon-Nicolet National Forest (CNNF) Climate Change Response Framework." This model forest pilot study will integrate climate predictions, social perspectives and needs, and adaptation and mitigation strategies in the CNNF within the context of all lands in northern Wisconsin. NRS is working closely with the public and private forest land managers in the study region, and with university partners, to conduct assessments of climate variability and mitigation potential. Increasingly, current and future impacts of climate change and how to respond are questions requiring answers by land managers as they need to respond to formal challenges of forest plans and projects. Incorporating the long-term outlook for climate and managing risks associated with climate variability and disturbance are new challenges for land managers and researchers who must work together to develop and implement adaptive management solutions for sustaining future forests.
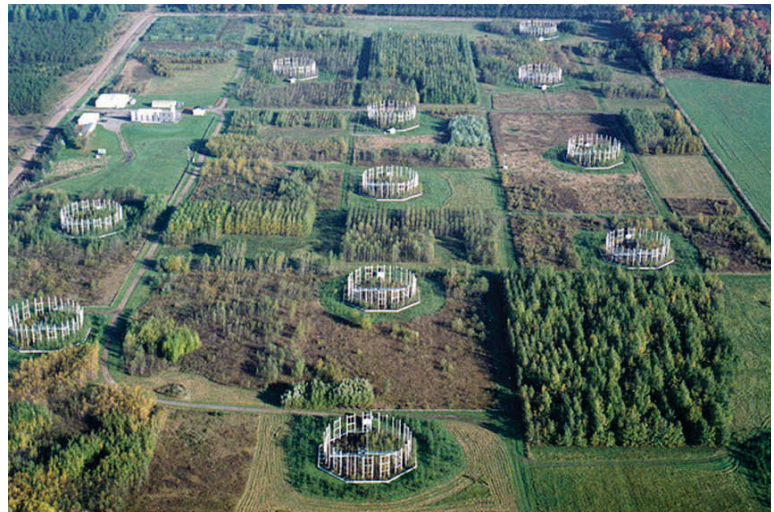
FISCAL YEAR 2010 NEW INITIATIVES

In FY 2010, NRS received new funding to continue the Aspen-FACE experiment in Rhinelander, WI, and was asked to provide leadership to address three national research priorities. In addition, the NRS is supporting the national initiative to implement landscape-scale conservation. This section describes the new research getting started in FY 2010, how it builds on the accomplishments reported for FY 2009, and the expected outcomes.

Phase 2 of the Aspen-FACE Experiment

The NRS maintains the world's largest whole-ecosystem climate change experiment, the Free-Air Carbon dioxide Enrichment (FACE) experiment near Rhinelander, WI. This experiment simulates future atmospheric concentrations of CO_2 and ozone and their effects on aspen, maple, and birch. After 10 years of operation, the Aspen-FACE experiment has revealed important new knowledge about the interacting effects of increased atmospheric CO_2 and ozone pollution on growth of aspen and other species critical to industry and landowners of northern forests. When essential funding from DOE ended in FY 2009, the NRS provided funds to prepare the Aspen-FACE experiment site for continued operation. In 2010, NRS and Michigan Technological University will initiate a new phase of the experiment, which will examine the effects of greenhouse gasses on naturally regenerating aspen forests. The experiment will consist of replicated stands of

The Rhinelander FACE experiment.

regenerating aspen, birch, and maple treated with increased concentrations of atmospheric CO_2 and/or ozone. It is important to continue this research. This unique facility offers a "window into the future" of northern forest ecosystems to help guide today's management decisions. Continuing the Aspen-FACE experiment will provide definitive answers to key questions about carbon capture by forests, air quality standards, human health, and biodiversity.

Upgrading the Annual Greenhouse Gas Inventory of U.S. Forests

The goal of this national project is to improve the official inventory of carbon in forests and wood products, and other greenhouse gas estimates, developed for the annual inventory reported by the U.S. Environmental Protection Agency (EPA) to meet requirements of the United Nations Framework Convention on Climate Change. With increasing attention to new domestic climate policy, the existing peer-reviewed and published methodologies need enhancements to provide the framework and guidelines for developing and delivering consistent estimates for the emergence of carbon markets and incentive programs that include forest offsets. The new methodology under development will allow estimates to be categorized by major land-use categories required for advanced reports: nonforest becoming forest, forest land remaining forest land, and forest becoming nonforest. Growth and natural disturbance effects will be explicitly included. To facilitate this work, NRS initiated a Forest Carbon Accounting and Research team within FIA.
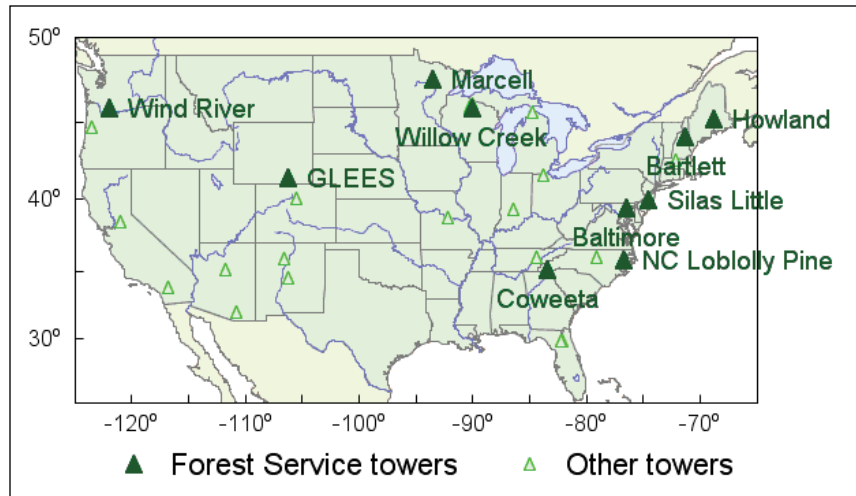
Expansion of the NRS Climate Tower Network

The objective of this new national initiative is to develop the capacity to assess and predict how climate change mitigation policies and programs to reduce greenhouse gases may be affected by changing climate and natural disturbances. Improved understanding is needed of the multiple interactions between climate, management, disturbance, and forest carbon storage, as well as improved models and decision-support capability. To this end, NRS is collaborating with other Forest Service research stations to add climate tower sites across the United States to better represent all forests. As part of this initiative, Forest Service research is fully implementing the national soil carbon assessment network, emphasizing new research on high-carbon forested peatlands, and developing methods to improve

The Forest Service climate tower research network.

projections of forest carbon and mitigation potential with emphasis on needs of the National Forest System. This integrated approach to carbon cycle science will provide the detailed information needed to dramatically increase stand-level knowledge of carbon cycle processes and make significant improvements in understanding the role of forests in global mitigation efforts. Improved knowledge of forest carbon cycling will advance the capability to project effects of mitigation strategies and land management on carbon stocks under climate change.

Helping People Respond to Climate Change

The goal of this new research thrust is to understand how people influence and respond to climate change. NRS scientists will study the social aspects of people's land use and management decisions and how those decisions influence forest carbon and greenhouse gas emissions. This research involves communities of people, their institutions, and their capacity to adapt to disturbances associated with climate change. The work also involves assessment of the social costs, benefits, and distributional impacts of public policies to enhance forest carbon sequestration and adaptation to climate change. Carbon markets, taxes, regulations, and other new or modified institutions have been proposed as mechanisms to influence land use and management to enhance forest carbon sequestration and sustain ecosystems in the face of climate change. NRS will determine direct and indirect effects of those policies and institutions on forest landowners, wood products processors, users of nontimber forest products, and people and communities throughout the urban-rural matrix. Science delivery mechanisms associated with this research include improvements to decision-support tools, participation in assessments of land management potentials for

Clearing forest for housing development in Pennsylvania.

mitigation, and scientific exchange with other countries. Information will be useful in devising assistance, outreach, and educational programs targeted towards increasing family forest landowner participation in carbon sequestration and offset programs.

Landscape-scale Conservation and Climate Change

U.S. Department of Agriculture Secretary Thomas Vilsack and Forest Service Chief Thomas Tidwell emphasize the challenges climate change poses to water and water-related ecosystem services and propose an "all lands" approach to address these threats. Chief Tidwell requested that the Regions, Stations, and Area work in regional partnerships to prepare action plans for landscape conservation, using climate change as a theme to integrate and streamline existing national and regional ecological restoration, fire and fuels, forest health, and biomass utilization strategies. The U.S. Forest Service in the Northeast and Midwest and the Northeastern Area Association of State Foresters (NAASF) offer an inclusive vision of landscapes and landscape-scale conservation designed to address these and other threats by reaching across ownership boundaries. This integrated approach recognizes that public benefits as well as forest threats cross boundaries and are best addressed through partnerships and infrastructure (markets, resource professionals, and information). Examples of this collaboration include: development of the Northern Forest Futures Project; submission of project proposals and strategies for the EPA-led Great Lakes Restoration Initiative; implementation of the Upper Mississippi River forestry partnership; and design and implementation of the Climate Change Response Framework for the Chequamegon-Nicolet National Forest and the northern part of Wisconsin.

Planning restoration of bottomland hardwoods in Mississippi.

International Research and Synthesis Networks

NRS scientists are leading or participating in several international collaborative research and scientific synthesis networks. The Integrated Network for Terrestrial Ecosystem Research on Feedbacks to the Atmosphere and Climate, sponsored by the National Science Foundation, is designed to (1) increase communication among experimentalists, ecosystem process modelers, and earth system modelers; (2) incorporate realistic terrestrial biogeochemical responses and feedbacks into earth system models; and (3) facilitate the design of a new generation of global change field experiments and ecosystem model simulations that can be used to improve the performance of earth system models. The International Precipitation Meta-analysis Project is a team effort to synthesize existing data from 33 experiments investigating the effects of experimental changes in the quantity and distribution of precipitation on terrestrial ecosystems. The team consists of 25 scientists from 11 countries. The Global Forest Carbon Inventory Project is an effort involving a dozen scientists from the United States and other countries to assemble the latest inventory data and data from ecosystem studies for estimating role of global forests in the carbon cycle, discovering the causes of observed changes in carbon stocks and assessing the prospects for global forests to continue sequestering carbon over the next several decades.

PRIORITIES FOR FISCAL YEAR 2011

Anticipated priorities for FY 2011 are to continue implementing the growth elements described in this report and the NRS climate change strategic plan. Excellent progress has been made toward meeting the long-term vision of a fully funded climate change research program that takes full advantage of the NRS research capacity. Priorities for FY 2011 continue this journey with additional emphasis in five program areas. The priorities described here represent NRS research plans and do not reflect the actual status of the FY 2011 budget by the U.S. Administration and Congress.

Respond to New International Requirements for Inventory, Monitoring, and Assessment

As countries move toward a global response to climate change, there is an urgent need to advance scientific leadership and provide technical assistance to international efforts in inventory, monitoring, and assessment. Deforestation and forest degradation in countries with primary tropical forests contribute as much as 20 percent of the world's greenhouse gas (GHG) emissions. Scientific and technical assistance for carbon inventories in developing countries, with an emphasis on integrating remote sensing with ground-based methodology and measurements, provides information to improve the environment by facilitating engagement in emerging international programs to mitigate and adapt to climate change. Special attention will be given to assessing the status of the largest and most vulnerable carbon stocks in the United States and abroad (see peatland research program described on page 12), and ecosystems that are considered particularly vulnerable to changing climate, such as the prairie-forest border in the Great Lakes Region.

Sampling a *Rhizopohra apiculata* tree in a mangrove forest East Kalimantan, Borneo, Indonesia. Photo by Boone Kauffman and Dan Donato, U.S. Forest Service.

Increase Use of Bioenergy, Minimizing Environmental Impacts, and Protecting Forest Health

Prospects for increased use of wood for bioenergy in the United States create a need to develop management practices that lead to increased biomass production without endangering ecosystem health. Specific bioenergy projects under consideration include assessing the environmental, economic, and social impacts of biomass harvesting in the western Great Lakes States; and assessing different biomass alternatives for agroforestry systems in Iowa. There is also interest in expanding research on the impacts of pests and diseases on tree mortality as affected by a changing climate, and the dynamics of rapidly increasing stocks of dead wood in the nation's forests. NRS is planning to synthesize the available literature on the effects of climate on diseases of eastern forests and to enhance monitoring of dead-wood dynamics following natural disturbance events at NRS Experimental Forests. These studies are necessary to improve our ability to foresee major changes that are likely to have significant impacts on ecosystem services over the next few decades as demands for fuel and fiber may increase dramatically.

New Peatlands Research Program

Peatlands cover 3 percent of the Earth's land area but contain about 30 percent of the planet's soil carbon and one-sixth of the global terrestrial fixed carbon. Peatlands play a very important, yet poorly quantified role in global carbon cycles. These unique wetlands provide a large suite of ecosystem services including influences on water quality and quantity, biodiversity, and long-

term carbon sinks. The important ecosystem services provided by peatlands, combined with their vulnerability to climate and land use change, call for an improved understanding of their current status and future condition. If climate or land-use change leads to increases in CO_2 or methane losses from peatlands, atmospheric concentrations of CO_2 and methane would accelerate the rate of climate change. FY 2011research plans include a synthesis of what is known and unknown about the status of the world's peatlands, and initiation of three major new studies:

- **SPRUCE (Spruce and Peatland Responses Under Climate and Environmental Change).** The northern Minnesota SPRUCE experiment involves manipulation of temperature and atmospheric CO_2 in a black spruce-*Sphagnum* peatland forest. This ecosystem, located at the southern extent of the spatially expansive boreal peatland forests, is considered to be especially vulnerable to climate change and to have important feedbacks to the atmosphere. It provides an excellent opportunity to investigate how climatic change will alter the interplay between vegetation dynamics and ecosystem vulnerability, while addressing critical uncertainties about feedbacks through the global carbon cycle. The SPRUCE experiment is a joint venture among the U.S. Forest Service, U.S. Department of Energy, and Oak Ridge National Lab.

- **PEATCOSM (Peatland Climate Change Experiment at the Houghton Mesocosm Facility).** The PEATCOSM experiment addresses the effects of climate change on a *Sphagnum*, Ericaceae, and sedge-dominated peatland ecosystem and the potential carbon dioxide feedbacks from these systems to the climate. Phase I manipulations include altered vegetation and water balance, and Phase II manipulations under consideration include an additional treatment combining elevated temperature and CO_2.

- **The Indo-Pacific Forest Carbon Study.** Tropical peat forests consisting of freshwater swamps and mangroves are among the largest terrestrial carbon pools on earth and provide a variety of ecosystem services, yet, rates of deforestation and fire in tropical peatlands are amongst the highest on Earth and are significant sources of greenhouse gasses arising from terrestrial carbon sources. This study seeks to ascertain the ecosystem carbon pools of these forested peatlands and the dynamics associated with land use/land cover change. This information is needed to improve sustainable management of these important ecosystems as well as participation in global greenhouse gas reduction financing strategies.

Improve Understanding of How People Influence and Respond to Climate Change

This growth area has three components: (1) Study the social aspects of people's land use and management decisions and how those decisions influence forest carbon and greenhouse gas emissions; (2) Study communities of people and their capacity to adapt to disturbances associated with climate change; and (3) Assess the social costs, benefits, and distributional impacts of public policies to enhance forest carbon sequestration. In recent years it has become clear that biological understanding is not sufficient for mitigating and adapting to climate change. Therefore it is necessary to facilitate much better integration among scientific disciplines so that social factors can be fully accounted for in developing responses.

Assess Climate Change Impacts, Adaptation, and Mitigation

These activities provide fundamental information to support land-management decisions about ecosystem adaptation and mitigation. NRS scientists are repeatedly called upon to participate in global, national, regional, and landscape-level carbon and ecosystem assessment or synthesis activities. The National Forest System in particular is facing increasing needs to respond to administrative mandates and public demands to include climate-change mitigation and adaptation in planning processes. Therefore it is necessary to strengthen the Northern Research Station's ability to provide the scientific basis for management responses, including assessment of the uncertainties and how to manage for a dynamic future environment.

LONG-TERM PRIORITIES

NRS envisions a fully funded climate change research program with a good balance addressing long-term research capacity (infrastructure and human resources), medium-term projects, and short-term needs for supporting emerging issues in policy and land management. Climate change research at NRS supports the four elements of the national research strategy and the seven goals of the Forest Service Strategic Framework for Responding to Climate Change (See pages 2 and 3).

The NRS strategic plan for climate change (see footnote 1, page 3) includes 12 growth areas for investing funding increases that will build capacity to meet the needs of the region's land managers and address urgent national priorities. These growth areas, totaling +$5.4 million, were developed in connection with strategic planning by the National Forest System, Northeastern Area, and the National Strategic Framework. NRS has responded well to increasing funding through FY 2010 by aggressively increasing emphasis on climate change research, and will continue to do so if past increases are sustained or if funding is increased in the future to reach the target of a fully implemented program.

The following list shows the topic areas and cumulative budget increases needed (over the FY 2008 base funding), by program element, to attain a fully implemented climate change research program at NRS.

Carbon Cycle Science

Numbers correspond to items on Table 6, page 18.

1. Fully implement a regional flux tower network by improving the technology and deployment of advanced observation systems and data delivery at NRS Experimental Forests and National Forests, to inform managers and policy makers about effects of management decisions on climate and effects of climate on ecosystems (+$400,000).

2. Establish a national soil carbon observation network to improve ability to forecast effects of climate change on vulnerable soil carbon stocks (+$400,000).

Inventory and Monitoring

3. Improve annual carbon inventory to monitor and verify the changes in carbon storage that result from land-use change, forest management, and wood product substitution (+$400,000).

Flux tower. Photo by Maria Janowiak, MIchigan Technological University.

4. Improve ability to detect climate change impacts by developing improved indicators and a regional strategy for early detection (+$400,000).

Carbon Management

5. Improve understanding of silviculture effects on carbon pools at NRS Experimental Forests to sustain and enhance productive, healthy, resilient ecosystems to deliver the values, goods, and services that people want (+$400,000).

6. Provide expert scientific support, customized analyses, and demonstration projects to support carbon policy and management decisions by international, Federal, State, and private interests (+$200,000).

7. Develop decision-support tools to help manage forests for climate mitigation and adaptation, and facilitate good planning and decisionmaking by public and private land managers (+$200,000; note: the amount of increase is higher in early years then reduced).

Atmospheric Deposition and Watersheds

8. Improve understanding of ecosystem processes and impacts of climate change, air pollution, and natural disturbances on watersheds and water quality (+$600,000).

Effects of Climate Change and Air Quality on Ecosystems

9. Continue operating the Rhinelander, WI, large-scale ecosystem experiment by initiating the next generation research to follow the Aspen-FACE study after it is decommissioned by DOE (+$1,000,000).

10. Improve ability to link land management actions with global climate models for analysis of policy implications from deployment of alternative mitigation and adaptation activities (+$300,000).

11. Integrate climate scenarios, regional weather modeling, landscape disturbance, and forest succession/species shift models to develop risk maps at multiple scales of significant changes in vegetation, fire and fuel regimes, and water quality and quantity (+$500,000).

Social Impacts and Adaptation

12. Provide additional support to understand the socioeconomic aspects of climate change impacts and mitigation strategies; reduce barriers to technology deployment; and design of policies such as carbon trading systems and incentives for carbon sequestration and abatement (+$600,000).

APPENDIX 1
NRS CLIMATE CHANGE RESEARCH BUDGET SUMMARY FY 2008—2010

From 2008 to 2010, the U.S. Congress provided an additional $12.5 million for climate change research to the USDA Forest Service. The Northern Research Station's share of this is $3.889 million through FY 2010 (including funding for national projects managed by NRS.) The 2010 Omnibus Spending Bill included an increase of $5.0 million above FY 2009 for climate change research by the U.S. Forest Service.[10] The cumulative additional funding needs for the NRS to specifically address the strategic plan in FY 2010 total $3.8 million. The cumulative additional funding received in FY 2010 over the base program is $3.889 million (Table 2), which includes funds for national projects that will be redirected to other Forest Service Research Stations. The total climate change research program at NRS in FY 2010 is $11.9 million, substantially more than the base program of FY 2008 (Table 3).

NRS Allocation of FY 2010 Climate Change Growth Funding

NRS submitted proposals for new research to Washington, D.C., in early December 2009. The WO recommended three proposals for NRS to lead, for a total additional funding of $1.6 million, and focusing mainly on climate change mitigation. In addition, NRS received $1.1 million for continuation of the modified Aspen-FACE (Phase 2, also known as the Northern Forest Ecosystem Experiment) for a total of $2.7 million in 2010 (Table 4). This is from a total funding increase of $5.0 million in 2010 for Climate Change Management for the U.S. Forest Service. Since funding increases in Climate Change Management began in 2008, NRS has received a total of $3.889 million of the total $12.5 million appropriated by the Congress (Table 3). The USDA Forest Service Research and Development mission area has further recommended that the Stations utilize the available funding in concert with the following formula: long-term capacity (60 percent); mid-term needs (30 percent multi-station projects); and, short-term urgent needs (10 percent).

Table 6 illustrates the funding detail in climate change for the FY 2008 base year, the FY 2009 increments, and the FY 2010 allocation. Funding needed to keep pace with strategic plans is shown for FY's 2010 through 2012.

Table 2.—Northern Research Station Program Component (dollars in millions)

	Base Program (FY 2008)	NRS 2010 Cumulative Needs	NRS 2010 Final Allocation	Total NRS Needs Year 5
Carbon cycle science	$1.712	+$0.800	+$0.985	+$0.800
Inventory and monitoring	0.664	+0.400	+0.600	+0.800
Carbon management	1.709	+0.700	+0.270	+0.700
Atmospheric deposition and watersheds	1.806	+0.200	+0.080	+0.600
Climate and air quality impacts	1.844	+1.400	+1.581	+1.900
Social impacts and adaptation	0.279	+0.300	+0.374	+0.600
Totals	**$8.014**	**+$3.800**	**+$3.889**	**+$5.400**

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[10]2010 Interior Conference Bill 10/30/09.

Table 3.—Northern Research Station Growth Opportunity Goal (dollars in millions)

	FY 2008	FY 2009	FY 2010	FY 2011[a]	FY 2012	Total
Science-based understanding (annual increase needed)	$0.500	$1.200	$2.100	$0.900	$0.700	$5.400
Actual appropriations (annual increase received)	0.195	0.994	2.700	-1.241		
Actual appropriations (cumulative increase received)	0.195	1.189	3.889	2.648		
Base program	8.014	8.014	8.014	8.014		
Total Program	**$8.209**	**$9.203**	**$11.903**	**$10.689**		

[a]President's budget

Table 4.—FY 2010 National Funds Allocated to NRS with Amounts Transferred to Other Stations, by Program Element (dollars in thousands)

	Gross Allocation to NRS[a]	Amount To PNWRS	Amount To PSWRS	Amount To RMRS	Amount To SRS	Amount To FPL	Net To NRS
Assessment[b]	500	40	--	--	--	63	397
Carbon Cycle Science:							
Tower network	400	100	--	100	100	--	100
Soil carbon	200	--	120	--	--	--	80
Projections	120	--	--	--	--	--	120
Decision support	80	--	--	--	--	--	80
Subtotal, Carbon Cycle Science	800	100	120	100	100	--	380
Economic and Social Science	300	60	--	--	--	--	240
Subtotal	1,600	200	120	100	100	--	1,080
Aspen-FACE (Phase 2)	1,100	--	--	--	--	--	1,100
Totals	**2,700**	**200**	**120**	**100**	**100**	**63**	**2,117**

[a]Budget allocation to the Northern Research Station in support of a national Climate Change Management program. Funds allocated to other Stations from the NRS are designed to ensure a strong science contract within each Program Element.

[b]Discussions are under way with FPL and other Stations for additional transfers within this Program Element.

Table 5.—Summary of Cumulative Funding Increases to NRS, 2008-2010, by Program Focus (dollars in thousands)

	Project Funding (excluding Aspen-FACE Phase 2)	Aspen-FACE Phase 2	Total Allocation
Long-term capacity	$1,581.0 (57%)	$900.0 (82%)	$2,481.0 (64%)
Medium-term projects	999.5 (36%)	150.0 (14%)	1,149.5 (30%)
Short-term flexibility	208.5 (7%)	50.0 (4%)	258.5 (7%)
Total	**$2,789.0 (100%)**	**$1,100.0 (100%)**	**$3,889.0 (100%)**

Table 6.—Northern Research Station Growth Opportunity Elements (dollars in thousands)

	2008 Base	2009 Need	Actual Funding Received 2009 Addition to NRS base (+1,189)	Actual Funding Received 2009 National funds to NRS (+418)	Actual Funding Received 2010 Addition to NRS base (+1,189)	Actual Funding Received 2010 National funds to NRS (+2,700)	Increase Needed to Base 2010 Need	Increase Needed to Base 2011 Need	Increase Needed to Base 2012 Need
Carbon cycle science:	$1,712								
(1) Fully implement national climate tower network, data management, and modeling		$100	$100		$105	$600	$500	$400	$400
(2) Establish national soil carbon network and improve soil carbon science and modeling		200	80		80	200	300	400	400
Inventory and monitoring:	664								
(3) Improve annual carbon inventory and decision support		200		175		500	300	400	400
(4) Improve detection of climate change impacts		100	80		100		100	200	400
Carbon management:	1,709								
(5) Silviculture effects on carbon pools (Experimental Forest Initiative)		100	75		60		200	200	400
(6) Support for Carbon Management Science Delivery[a]		0	105	85			100	200	200
(7) Carbon management decision-support		400	255		210		400	300	200
Atmospheric deposition and watersheds:	1,806								
(8) Improve understanding of ecosystem processes and ecosystem modeling		100	40		80		200	300	600
Effects of climate and air quality on ecosystems:	1,844								
(9) Large-scale ecosystem experiment (also highly relevant to carbon cycle science)[b]		100	35			1,100	1,000	1,000	1,000
(10) Model processes of climate variability and change		100	50		75		200	300	300
(11) Improving understanding of climate change and disturbance impacts		200	295	25	357		200	400	500
Social impacts and adaptation:	279								
(12) Assessing impacts and delivering science for society's benefit		100	74	133	74	300	300	600	600
Total base program	**$8,014**								
Total increases and needs		$1,700	$1,189	$418	$1,189	$2,700	$3,800	$4,700	$5,400

[a]Included in row 3 in FY 2010 (improve annual carbon inventory and decision support)

[b]Renewal of Aspen-FACE in Rhinelander, WI

APPENDIX 2
FY 2005-2009 NRS ACCOMPLISHMENTS OF THE BASE PROGRAM

Following are some of the more significant accomplishments of the base climate change research program from the last 5 years.

CARBON CYCLE SCIENCE

Carbon cycle science involves basic research approached through controlled experiments, eddy-flux observations at intensive monitoring sites, and models aimed at understanding the complex interactions between the carbon cycle and other factors such as nitrogen deposition.

Research Description

Flux Tower Network

NRS maintained and operated a network of flux towers at Howland Research Forest, Maine; Bartlett Experimental Forest, New Hampshire; Silas Little Experimental Forest, New Jersey; Marcell Experimental Forest, Minnesota; and Baltimore Long-term Ecological Research Site, Maryland. The flux towers provide high-resolution monitoring of forest/atmosphere CO_2 exchange, and also monitor meteorology, radiation and water balance. Recent accomplishments include new knowledge about insect defoliation impacts on ecosystem productivity, quantification of the effect of lengthening growing season on net annul carbon uptake, and many other significant discoveries about controls on carbon cycling and key processes for guiding model development.

Soil Carbon Research

Current research emphasizes improved understanding of belowground processes, as knowledge gaps in this area most limit understanding of carbon cycle science and ecosystem resilience. Specialized research facilities include a Rhizotron for direct observation of soil and a recently constructed mesocosm for manipulative experiments, both located in Houghton, MI. Recent accomplishments include discovery of how soil microorganisms influence many key soil-related ecosystem processes and services such as tree health and productivity, soil carbon storage, nutrient cycling and water quality, and how greenhouse gases affect the symbiotic fungi that help trees get nutrients from the soil.

Science Delivery

Delivery of information from the carbon cycle science program element is performed under the "Carbon Management" and "Adaptation Response" program elements.

Impact on Management or Policy

Carbon cycle science forms the basis for credible and effective policy and decisionmaking regarding analysis of climate change mitigation opportunities and implementation of programs. The carbon cycle is also highly sensitive to climate change and vice versa—changes in the carbon cycle may have strong impacts on climate—so that implementation of an integrated approach to mitigation and adaptation requires basic understanding of the causes and effects of changes in forest carbon dynamics.

Recent Publications (selected)

Andrew, Carrie; Lilleskov, Eric A. 2009. **Productivity and community structure of ectomycorrhizal fungal sporocarps under increased atmospheric CO_2 and O_3.** Ecology Letters. 12(8): 813-822.

Bradford, J.B.; Birdsey, R.A.; Joyce L.A.; Ryan, M.G. 2008. **Tree age, disturbance history, and carbon stocks and fluxes in subalpine Rocky Mountain forests.** Global Change Biology. 14(12): 2882-2897.

Bradford, John; Weishampel, Peter; Smith, Mary-Louise; Kolka, Randall; Birdsey, Richard A.; Ollinger, Scott V.; Ryan, Michael G. 2009. **Detrital carbon pools in temperate forests: magnitude and potential for landscape-scale assessment.** Canadian Journal of Forest Research. 39(4): 802-813.

Clark, Kenneth; Skowronski, Nicholas; Hom, John. 2009. **Invasive insects impact carbon dynamics.** Global Change Biology.

Crow, Susan E.; Lajtha, Kate; Filley, Timothy; Swanston, Christopher W.; Bowden, Richard D.; Caldwell, Bruce A. 2009. **Sources of plant-derived carbon and stability of organic matter in soil: implications for global change.** Global Change Biology. 15(8): 2003-2019.

Fissore, Cinzia; Giardina, Christian P.; Swanston, Christopher W.; King, Gary M.; Kolka, Randall K. 2009. **Variable temperature sensitivity of soil organic carbon in North American forests.** Global Change Biology. 15(9): 2295-2310.

Froberg, Mats; Hanson, Paul J.; Trumbore, Susan E.; Swanston, Christopher W.; Todd, Donald E. 2009. **Flux of carbon from 14C-enriched leaf litter throughout a forest soil mesocosm.** Geoderma. 149(3): 181-188.

Gaudinski, J.B.; Torn, M.S.; Riley, W.J.; Swanston. C.; Trumbore, S.E.; Joslin, J.D.; Majdi, H.; Dawson, T.E.; Hanson, P.J. 2009. **Use of stored carbon reserves in growth of temperate tree roots and leaf buds: analyses using radiocarbon measurements and modeling.** Global Change Biology. 15(4): 992-1014.

King, J.S.; Giardina, C.P.; Pregitzer, K.S.; Friend, A.L. 2007. **Biomass partitioning in red pine (*Pinus resinosa*) along a chronosequence in the Upper Peninsula of Michigan.** Canadian Journal of Forest Research. 37(1): 93-102.

Lilleskov, Erik A.; Mattson, William J.; Storer, Andrew J. 2008. **Divergent biogeography of native and introduced soil macroinvertebrates in North America north of Mexico.** Diversity and Distributions. 14(6): 893-904.

Luyssaret, S.; Inglima, I.; Jungs, M.; Richardson, A.D.; Reichstein, M.; Papale, D.; Piao, S.L.; Schulze, E.D.; Wingate, L. 2007. **CO_2 balance of boreal, temperate, and tropical forests derived from a global database.** Global Change Biology. 13(12): 1-29.

Noormets, Asko; Chen, Jiquan; Crow, Thomas R. 2007. **Age-dependent changes in ecosystem carbon fluxes in managed forests in northern Wisconsin, USA.** Ecosystems. 10(2): 187-203.

Pan, Yude; Birdsey, Richard; Hom, John; McCullough, Kevin; Clark, Kenneth. 2006. **Improved estimates of net primary productivity from MODIS satellite data at regional and local scales.** Ecological Applications. 16(1): 125-132.

Potter, Christopher; Gross, Peggy; Genovese, Vanessa; Smith, Marie-Louise. 2008. **Storage of carbon in U.S. forests predicted from satellite data, ecosystem modeling, and inventory summaries.** Climatic Change. 90(3): 269-282.

Potter, Christopher; Gross, Peggy; Genovese, Vanessa; Smith, Marie-Louise. 2007. **Net primary productivity of forest stands in New Hampshire estimated from Landsat and MODIS satellite data.** Carbon Balance and Management. 2(9): 1-11.

Pouyat, Richard V.; Yesilonis, Ian D.; Nowak, David J. 2006. **Carbon storage by urban soils in the United States.** Journal of Environmental Quality. 35: 1566-1575.

Richardson, Andrew D.; Hollinger, David Y.; Dail, D. Bryan; Lee, John T.; Munger, J. William; O'Keefe, John. 2009. **Influence of spring phenology on seasonal and annual carbon balance in two contrasting New England forests.** Tree Physiology. 29(3): 321-331.

Sherrill, K.R.; Lefsky, M.A.; Bradford, J.R.; Ryan, M.G. 2008. **Forest structure estimation and pattern exploration from discrete-return lidar in subalpine forests of the central Rockies.** Canadian Journal of Forest Research. 38(8): 2081-2096.

Skowronski, Nicholas; Clark, Kenneth; Nelson, Ross; Hom, John; Patterson, Matthew. 2007. **Remotely sensed measurements of forest structure and fuel loads in the Pinelands of New Jersey.** Remote Sensing of the Environment. 108(2): 123-129.

Xiao, Jingfeng; Zhuang, Qianlai; Baldocchi, Dennis D.; Law, Beverly; Richardson, Andrew D.; Chen, Jiquan; Oren, Ram; Starr, Gregory; Noormets, Asko. 2008. **Estimation of net ecosystem carbon exchange for the conterminous United States by combining MODIS and AmeriFlux data.** Agricultural and Forest Meteorology. 148(11): 1827-1847.

Yang, Y.H.; Fang, J.Y.; Pan, Y.D.; Ji, C.J. 2009. **Aboveground biomass in Tibetan grasslands.** Journal of Arid Environments. 73: 91-95.

INVENTORY AND MONITORING

Inventory and monitoring refers to (1) extensive inventories by FIA that characterize the carbon stocks and changes in carbon stocks on the region's forest lands, a system that may also detect the impacts of climate change and other stressor on forests; and (2) intensive site-monitoring such as that often conducted at experimental forests.

Research Description

U.S. Forest Greenhouse Gas Inventory

FIA conducts annual forest inventories and analyses across the 20-state region and four Plains States, and provides annual estimates of forest carbon stocks and changes in forest carbon stocks for the U.S. greenhouse gas inventory. The greenhouse gas inventory is reported by the EPA to the United Nations Framework Convention on Climate Change. It includes comprehensive estimates of the Nation's forest-related carbon stocks, changes, and uncertainty. Recent findings continue to confirm that a large carbon sink in U.S. forests offsets about 12 percent of U.S. emissions of CO_2 from use of fossil fuels. The NRS has made significant and long-lasting contributions to the international and domestic protocols for measuring, monitoring, verifying, and reporting changes in carbon stocks for the forest sector.

Science Delivery

FIA data (including carbon estimates and methods) are easily accessible through the Internet and is widely used as a standard for monitoring and analysis of forest management and the carbon cycle. Methods developed to estimate forest and wood product carbon pools are widely adopted and have become the standard for U.S. analysis and reporting. Additional information about science delivery is included under the "Carbon Management" program element.

Impact on Management or Policy

The U.S. greenhouse gas inventory is the principal source of peer-reviewed, quantitative information about past and current trends in stocks of carbon in forests and wood products. Thus, the data are essential for formulating sound policies and programs for climate change management, and for monitoring the effectiveness of actions to reduce greenhouse gases under both domestic and international responses.

Recent Publications (selected)

Birdsey, R.A.; Jenkins, J.C.; Johnston, M.; Huber-Sannwald, E.; Amero, B.; de Jong, B.; Heath, L.S.; Pan, Y.; Pregitzer, K.S. 2007. **North American forests.** In: King, A.W.; Dilling, L.; Zimmerman, G.P., eds. The first state of the carbon cycle report (SOCCR): The North American carbon budget and implications for the global carbon cycle. Asheville, NC: National Oceanic and Atmospheric Administration: 117-126.

Birdsey, Richard; Bates, Nick; Behrenfeld, Mike; Davis, Kenneth; Doney, Scott; Richard, Feely; Hansell, Dennis; Heath, Linda; Kasischke, Eric. 2009. **Carbon cycle observations: Gaps threaten climate mitigation policies.** EOS. 90(34): 292.

Chen, Jiaxin; Columbo, Stephen J.; Ter-Mikaelian, Michael T.; Heath, Linda S. 2008. **Future carbon storage in harvested wood products from Ontario's Crown forests.** Canadian Journal of Forest Research. 38(7): 1947-1958.

Fast, Andrew J.; Ducey, Mark J.; Gove, Jeffrey H.; Leak, William B. 2008. **Dating tree mortality using log decay in the White Mountains of New Hampshire.** Northern Journal of Applied Forestry. 25(3): 154-157.

Pacala, S.; Birdsey, R.A.; Bridgham, S.D.; Conant, R.T.; Davis, K.; Hales, B.; Houghton, R.A.; Jenkins, J.C.; Johnson, M. 2007. **The North American carbon budget past and present.** In: King, A.W.; Dilling, L.; Zimmerman, G.P., eds. The first state of the carbon cycle report (SOCCR): The North American carbon budget and implications for the global carbon cycle. Asheville, NC: National Oceanic and Atmospheric Administration: 29-36.

Smith, Pete; Nabuurs, Gert-Jan; Janssens, Ivan A.; Reis, Stefan; Marland, Gregg; Soussana, Jean-Francois; Christensen, Torben R.; Heath, Linda; Apps, Mike. 2008. **Sectoral approaches to improve regional carbon budgets.** Climate Change. 88(3-4): 209-249.

U.S. Department of Agriculture. 2008. **U.S. agriculture and forestry greenhouse gas inventory: 1990-2005.** Tech. Bull. No. 1921. Washington, DC: U.S. Department of Agriculture, Office of the chief Economist, Global Change Program Office. 161 p. Available at www.usda.gov/oce/global_change/AFGGInventory1990_2005.htm.

U.S. Environmental Protection Agency. 2009. **Inventory of U.S. greenhouse gas emissions and sinks: 1990-2007.** EPA 430-R-09-004. Washington, DC: U.S. Environmental Protection Agency. Available at: http://www.epa.gov/climatechange/emissions/ usinventoryreport.html

Woodall, C.W.; Heath, L.S.; Smith, J.E. 2008. **National inventories of down and dead woody material forest carbon stocks in the United States: Challenges and opportunities.** Forest Ecology and Management. 256(3): 221-228.

Woodbury, Peter B.; Smith, James E.; Heath, Linda S. 2007. **Carbon sequestration in the U.S. forest sector from 1990 to 2010.** Forest Ecology and Management. 241: 14-27.

Zheng, Daolan; Heath, Linda S.; Ducey, Mark J. 2007. **Forest biomass estimated from MODIS and FIA data in the Lake States: MN, WI and MI, USA.** Forestry. 80(3): 265-278.

CARBON MANAGEMENT

Carbon management refers to development of silvicultural practices and management systems for increasing carbon sequestration and reducing or avoiding emissions from rural and urban forests, analyses to support greenhouse gas policies and programs, and development of accounting rules and guidelines to support emerging carbon registries and markets. Research on decision-support tools that allow managers to calculate carbon storage occurs primarily in the carbon management element.

Research Description

Experimental Forests and Synthesis

The NRS maintains 23 experimental forests, many with long-term silvicultural experiments and some with multiple flux towers to test treatment or condition effects. This infrastructure is a strong platform for adding value to existing long-term studies and for initiating additional experimental research. Recent accomplishments include analyses of gaps in terrestrial above- and belowground carbon data, identification of opportunities for increased carbon sequestration in forests, improvements in approaches to landscape-level monitoring of the belowground carbon cycle, syntheses of field methods for belowground carbon measurements, and improved understanding of carbon movement from plants into soils.

Science Delivery

The Carbon OnLine Estimator (COLE) is a Web-based tool for forest carbon analysis that generates carbon estimates based on FIA data for any part of the continental United States as large as a county, with uncertainty values decreasing for larger areas. Reports provide carbon "growth and yield" curves for strategic evaluation of potential mitigation strategies. In 2004, COLE was named the official 1605b Web-tool by the U.S. Departments of Agriculture and Energy. The Forest Vegetation Simulator (FVS) is used by most national forests to estimate the consequences of management activities, and now contains a module to estimate carbon stocks of inventoried and simulated stands, enabling managers to compare the carbon consequences of management alternatives. The Northern Institute of Applied Carbon Science (NIACS) is a regional collaborative effort composed of Federal (U.S. Forest Service Northern Research Station, Eastern Region, and Northeastern Area), industrial (National Council for Air & Stream Improvement), and higher education (Michigan Tech) organizations. NIACS develops and disseminates information on carbon cycle science for land managers in the Northern United States, applies methods and approaches to carbon inventory and monitoring at a variety of scales, and demonstrates carbon management in managed forests. For urban and community forests, the i-Tree suite of software tools (UFORE—Urban Forest Effects—model is one of the featured models) was developed to help users—regardless of community size or technical capacity—identify, understand, and manage urban tree populations. I-Tree also calculates avoided emissions, an important part of the full energy balance calculation.

Impact on Management or Policy

Carbon management research aims to support land management needs for information and decision-support tools to facilitate participation in carbon markets and registries, and to support "good practice for sustainable forest management."

Recent Publications (selected)

Birdsey, Richard; Pregitzer, Kurt; Lucier, Alan. 2006. **Forest carbon management in the United States 1600-2100.** Journal of Environmental Quality. 35: 1461-1469.

Birdsey, Richard A. 2006. **Carbon accounting rules and guidelines for the United States forest sector.** Journal of Environmental Quality. 35: 1518-1524.

Heath, Linda S.; Van Duesen, Paul C.; Spinney, Michael P.; Gove, Jeffery H.; Smith, James E. 2006. **COLE: Carbon online estimation web tool for continental U.S. forest ecosystems.** In: Proceedings of climate science in support of decision making; 2005 Nov. 13-16; Arlington, VA.

Hoover, Coeli M. 2008. **Field measurements for forest carbon monitoring: A landscape-scale approach.** New York, NY: Springer Science + Business Media. 242 p.

Hoover, Coeli; Rebain, Stephanie. 2008. **The Kane Experimental Forest carbon inventory: Carbon reporting with FVS.** In: Havis, Robert N.; Crookston, Nicholas L., comps. Third forest vegetation simulator conference; 2007 February 13-15; Fort Collins, CO. Proceedings RMRS-P-54. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 17-22.

Pearson, Timothy R.H.; Brown, Sandra L.; Birdsey, Richard A. 2007. **Measurement guidelines for the sequestration of forest carbon.** Gen. Tech. Rep. NRS-18. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 42 p.

Pouyat, Richard V.; Pataki, Diane E.; Belt, Kenneth T.; Goffman, Peter M.; Hom, John; Band, Lawrence. 2007. **Effects of urban land-use change on biogeochemical cycles.** In: Canadell J.G.; Pataki D.E.; Pitelka L.F., eds. Terrestrial ecosystems in a changing world. Berlin, Germany: Springer-Verlag: 45-58.

Smith, James E.; Heath, Linda S.; Skog, Kenneth E.; Birdsey, Richard A. 2006. **Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States.** Gen. Tech. Rep. NE-343. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 216 p.

Upton, Brad; Miner, Reid; Spinney, Mike; Heath, Linda S. 2008. **The greenhouse gas and energy impacts of using wood instead of alternatives in residential construction in the United States.** Biomass and Bioenergy. 32(1): 1-10.

ATMOSPHERIC DEPOSITION AND WATERSHEDS

Atmospheric deposition and watersheds is targeted toward improving our understanding of the effects of air pollution (mainly nitrogen and acid deposition) on ecosystem and watershed processes, structure, and function, since these effects have strong interactions with climate change.

Research Description

Experimental Forests

The NRS maintains 23 experimental forests, some with many years of experimental treatments of whole watersheds. This research has provided not only some very long-term data sets but also major advances in understanding of biogeochemical process and responses to air pollution, climate variability, and management.

Ecosystem Modeling

NRS maintains a wide variety of models for many different kinds of research and applications. A few examples include forest growth and yield models such as SILVAH, theoretical models such as Pipestem, disturbance models such as LANDIS, regional-scale climate models such as MM5, fire-danger models such as NFDRS, and ecosystem process models such as PnET-CN. Recent accomplishments have revealed how forests continue to absorb nitrogen deposition and other air pollutants and prevented their release into streams and estuaries, thus helping to maintain clean water. However, research also revealed that changes in soil nutrient status induced by acid deposition crossed a threshold necessary to sustain sugar maple growth during the 1970s on some sites.

Linking Atmospheric Deposition to the Health of Fish, Wildlife, and Human Populations

Due to the integration of ecosystem scientists, forest ecologists, and fish and wildlife biologists, the Center for Research on Ecosystem Change has linked atmospheric deposition of acid and mercury to bioaccumulation of highly valued and at-risk fish populations. Recent work highlights the importance of growth efficiency, which is strongly affected by acid deposition, forest change, and climate warming, as a determinant of mercury concentrations in stream fishes, with associated risks to human health.

Science Delivery

This is typically accomplished through participation in assessments and synthesis products that are designed to provide summaries of current knowledge for land managers and policy makers.

Impact on Management or Policy

Results have been used to develop guidelines for best management practices to sustain or improve water quality and productive, healthy forests to reduce the impact by air pollution.

Recent Publications (selected)

Adams, Mary B.; DeWalle, David R.; Hom, John L., eds. 2006. **The Fernow watershed acidification study.** Dordrecht, Netherlands: Springer. 279 p.

Lilleskov, Erik A.; Wargo, Philip M.; Vogt, Kristiina A.; Vogt, Daniel J. 2008. **Mycorrhizal fungal community relationship to root nitrogen concentration over a regional atmospheric nitrogen deposition gradient in the northeastern USA.** Canadian Journal of Forest Research. 38: 1260-1266.

Long, Robert P.; Horsley, Stephen B.; Hallett, Richard A.; Bailey, Scott W. 2009. **Sugar maple growth in relation to nutrition and stress in the northeastern United States.** Ecological Applications. 19(6): 1454-1466.

Murdoch, Peter S.; Jenkins, Jennifer C.; Birdsey, Richard A. 2008. **The Delaware River Basin collaborative environmental monitoring and research initiative: Foundation document.** Gen. Tech. Rep. NRS-25. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. Executive summary, 15 p.; online foundation document, 93 p.

Pregitzer, Kurt S.; Burton, Andrew J.; Zak, Donald R.; Talhelm, Alan F. 2008. **Simulated chronic nitrogen deposition increases carbon storage in Northern temperate forests.** Global Change Biology. 14(1): 142-153.

Scheller, R.M.; Domingo, J.B.; Sturtevant, B.R.; Williams, J.S.; Rudy, A.; Gustafson, E.J.; Mladenoff, D.J. 2007. **Design, development, and application of LANDIS-II, a spatial landscape simulation model with flexible temporal and spatial resolution.** Ecological Modelling. 201: 409-419.

Ward, D.M; Nislow, K.H.; Chen, C.Y.; Folt, C.L. 2010. **Rapid, efficient growth reduces mercury concentrations in stream-dwelling Atlantic-salmon.** Transactions of the American Fisheries Society. 139: 1-10.

EFFECTS OF CLIMATE AND AIR QUALITY ON ECOSYSTEMS

Effects of climate and air quality on ecosystems is a broad topic area designed to develop the scientific knowledge needed for adaptation, and targets effects of climate change, climate variability, and air pollution on species and ecosystems at multiple scales. Because the range of impacted species and ecosystems is so large, research in this area is targeted toward key species and the most important ecosystems. Two large-scale experiments are included in this program element: the Aspen-FACE study, and the SPRUCE peatland warming experiment at Marcell Experimental Forest. This program element also examines feedbacks of changes in the land surface to the climate system.

Research Description

The Aspen-FACE Experiment

NRS maintains the world's largest whole-ecosystem climate change experiment, the Free-Air Carbon dioxide Enrichment (FACE) experiment near Rhinelander, WI. This experiment simulates future atmospheric concentrations of CO_2 and ozone and their effects on aspen, maple, and birch. After 10 years of operation, the Aspen-FACE experiment has revealed important new knowledge about the interacting effects of increased atmospheric CO_2 and ozone pollution on growth of aspen and other species critical to industry and landowners of northern forests.

The SPRUCE Experiment

The Spruce-Peatland Response Under Climate and Environmental Change (SPRUCE) experiment is a climate change manipulation examining the response of northern peatland ecosystems to multiple levels of soil and atmosphere warming at ambient or elevated carbon CO_2 levels. These treatments simulate climate change impacts. The research will lead to breakthroughs in our understanding of how climate change will affect the vulnerability of plant species, the overall carbon balance of these carbon rich ecosystems, and the net effect on ecosystem services from peatlands. In addition, the data collected in the SPRUCE experiment will be directly used to redefine models that will predict the fate of carbon-rich peatland systems and their feedbacks to the atmosphere worldwide.

Impacts of Land Management on the Climate System

NRS is developing new knowledge about the effect of albedo (reflectance of energy) on global warming potential, which may counteract the positive effect of increasing carbon sequestration from afforestation and other land management activities. This research uses high performance computers in East Lansing, MI, to test the performance of the climate models and to initiate sensitivity studies of afforestation effects on climate at the regional scale. Research results have been published on the functional relations and potential climate feedbacks associated with canopy nitrogen, carbon assimilation, and albedo in temperate and boreal forests.

Modeling Impacts of Climate Change, Climate Variability, and Disturbances on Ecosystems

Currently, NRS has a mixed program of modeling impacts of climate change on ecosystems, with most of the effort concentrated on effects on tree and bird species distributions. In 2009, NRS began collaboration with the Ohio Supercomputing Center to model to assess the colonization potentials of tree species more realistically under current fragmented landscapes and also under future species abundances according several climate projections (Global Circulation Models). There is additional research under way on impacts of fire, and a long-term program of research on impacts of invasive pests.

Climate Change and Impacts on Forests of Northeastern U.S. and Eastern Canada

A project titled NE Forests 2100 was initiated in 2005 and is led by NRS scientists. The goals of this international team of over 20 members are to summarize climate change research on northern forest ecosystems in the northeastern United States and eastern Canada and to provide current information on regional climate variability and change to policy makers, land managers, and the concerned public. The team produced a special issue of the Canadian Journal of Forest Research reporting results of the project.

Science Delivery

NRS continued a project begun in FY 2008 called "Forest Management for an Uncertain Climate Future," involving nine seminars and workshops to educate forest managers about climate change and help them begin planning for climate change adaptation. NRS initiated the Chequamegon-Nicolet National Forest Climate Change Response Framework, which will integrate climate predictions, social perspectives and needs, and adaptation and mitigation strategies in the CNNF and northern Wisconsin. NRS launched a partnership with Cornell University to strengthen science delivery related to the Climate Change Atlas, and collaborated with the Union of Concerned Scientists, who used our projections of change in bird and tree species habitat in their reports of climate change effects in their Northeastern and Pennsylvania reports.

Impact on Management or Policy

Increasingly, current and future impacts of climate change and how to respond are questions requiring answers by land managers as they need to respond to challenges to forest plans and projects. Incorporating the long-term outlook for climate and managing risks associated with climate variability and disturbance is a new challenge for land managers.

Recent Publications (selected)

Campbell, J.L.; Rustad, L.; Boyer, E.W.; Christopher, S.F.; Driscoll, C.T.; Fernandez, I.J.; Groffman, P.M.; Houle, D.; Kiekbusch, J.; Magill, A.H.; Mitchell, M.J.; Ollinger, S.V. 2009. **Consequences of climate change for biogeochemical cycling in forests of northeastern North America.** Canadian Journal of Forest Research. 39: 264-284.

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Dewar, Roderick C.; Franklin, Oskar; Makela, Annikki; McMurtrie, Ross E.; Valentine, Harry T. 2009. **Optimal function explains forest responses to global change.** BioScience. 59(2): 127-139.

Gaige, E.; Dail, D.B.; Hollinger, D.Y.; Davidson, E.A.; Fernandez, I.J.; Seivering, H. 2007. **Changes in canopy processes following whole-forest canopy nitrogen fertilization of a mature spruce-hemlock forest.** Ecosystems. 10(7): 1133-1147.

Giardina, Christian P.; Coleman, Mark D.; Hannock, Jessica E.; King, John S.; Lilleskov, Erik A.; Loya, Wendy M. 2005. **The response of belowground carbon allocation in forests to global change.** In: Binkley, D.; Menyailo, O., eds. Tree species effects on soils: Implications for global change. Dordrecht, Netherlands: Kluwer Academic Publishers: 119-154.

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Karnosky, D.F.; Pregitzer, K.S. 2006. **Impacts of elevated atmospheric [CO2] and [O3] on northern temperate forest ecosystems: results from the Aspen FACE experiment.** Ecological Studies. 187: 213-229.

Kliejunas, John T.; Geils, Brian W.; Glaeser, Jessie Micales; Goheen, Ellen Michaels; Hennon, Paul; Kim, Mee-Sook; Kope, Harry; Stone, Jeff; Sturrock, Rona; Frankel, Susan J. 2009. **Review of literature on climate change and forest diseases of western North America.** Gen. Tech. Rep. PSW-225. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 54 p.

Kubiske, Mark E.; Quinn, Vanessa S.; Heilman, Warren E.; McDonald, Evan P.; Marquardt, Paula E.; Teclaw, Ron M. 2006. **Interannual climatic variation mediates elevated CO_2 and O_3 effects on forest growth.** Global Change Biology. 12: 1-15.

Liu, Lingli; King, John S.; Giardina, Christian P; Booker, Fitzgerald L. 2009. **The influence of chemistry, production and community composition on leaf litter decomposition under elevated atmospheric CO_2 and tropospheric O_3 in a northern hardwood ecosystem.** Ecosystems. 12(3): 401-416.

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Noormets, A.; Desai, A.R.; Cook, B.D.; Euskirirchen, E.S.; Ricciuto, D.M.; Davis, K.J.; Bolstad, P.V.; Schmid, H.P.; Vogel, C.V. 2008. **Moisture sensitivity of ecosystem respiration: Comparison of 14 forest ecosystems in the Upper Great Lakes Region, USA.** Agricultural and Forest Meteorology. 148(2): 216-230.

Pan, Yude; Birdsey, Richard; Hom, John; McCullough, Kevin. 2009. **Separating effects of changes in atmospheric composition, climate and land-use on carbon sequestration of U.S. Mid-Atlantic temperate forests.** Forest Ecology and Management. 259: 151-164.

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Percy, K.E.; Nosal, M.; Heilman, W.; Dann, T.; Sober, J.; Legge, A.H.; Karnosky, D.F. 2007. **New exposure-based metric approach for evaluating O3 risk to North American aspen forests.** Environmental Pollution. 147: 554-566.

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Rodenhouse, N.L.; Matthews, S.N.; McFarland, K.P.; Lambert, J.D.; Iverson, L.R.; Prasad, A.; Sillett, T.S.; Holmes, R.T. 2008. **Potential effects of climate change on birds of the Northeast.** Mitigation and Adaption Strategies for Global Change. 13(5): 517-540.

Rustad, L.E. 2006. **From transient to steady state response of ecosystems to atmospheric CO_2-enrichment and global climate change.** Plant Ecology. 182: 43-62.

Rustad, LE. 2008. **The response of terrestrial ecosystems to global climate change: Towards an integrated approach.** Science of the Total Environment. 404: 222-235.

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Ryan, M.; Archer, S.; Birdsey, R.; Dahm, C.; Heath, L.; Hicke, J. 2008. **Land resources: Forests and arid lands.** In: The effects of climate change on agriculture, land resources, and biodiversity. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Washington, DC: U.S. Climate Change Science Program: 75-120.

Scheller, Robert M.; Mladenoff, David J. 2008. **Simulated effects of climate change, fragmentation, and inter-specific competition on tree species migration in northern Wisconsin, USA.** Climate Research. 36(3): 191-202.

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Sturtevant, B.R., Miranda, B.R.; Yang, J.; He, H.S.; Gustafson, E.J.; Scheller, R.M. 2009. **Studying fire mitigation strategies in multi-ownership landscapes: Balancing the management of fire-dependent ecosystems and fire risk.** Ecosystems. 12: 445-461.

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Williams, M.; Richardson, A.D.; Reichstein, M.; Stoy, P.C.; Peylin, P.; Verbeeck, H.; Carvalhais, N.; Jung, M.; Hollinger, D.Y. 2009. **Improving land surface models with FLUXNET data.** Biogeosciences. 6(7): 1341-1359.

SOCIAL IMPACTS AND ADAPTATION TO CLIMATE CHANGE

Social Impacts and Adaptation to Climate Change seeks to understand how people, through their land use and management decisions, influence forest carbon and greenhouse gas emissions, and how communities may respond or adapt to disturbances associated with climate change in ways that result in positive benefits to society. *Ecosystem Adaptation and Assessments* provide support for NRS scientists to carry out climate change related ecosystem and carbon synthesis and assessment activities. These activities provide fundamental information in support of decisions about ecosystem adaptation and mitigation.

Research Description

Social Science Research

The goal of this integrated research is to understand how people influence and respond to climate change. NRS studies the social aspects of people's land-use and management decisions and how those decisions influence forest carbon and greenhouse gas emissions. NRS also studies communities of people, their institutions, and their capacity to adapt to disturbances associated with climate change. This research includes assessing the social costs, benefits, and distributional impacts of public policies to enhance forest carbon sequestration and adaptation to climate change. Carbon markets, taxes, regulations, and other new or modified institutions have been proposed as mechanisms to influence land use and management to enhance forest carbon sequestration and sustain ecosystems in the face of climate change. NRS will determine direct and indirect effects of those policies and institutions on forest landowners, wood products processors, users of nontimber forest products, and people and communities throughout the urban-rural matrix.

Science Delivery

In FY09, NRS collaborated with scientists at the Pacific Northwest Station on a study of forest and range management carbon offset projects on private lands in the United States. These case studies highlighted the motivations of landowners who undertake offset projects, the types of activities landowners are pursuing while enrolled in offset projects, challenges in developing offset projects, lessons learned, and suggestions for improvements to the process of enrolling in forest carbon offset program. Based on these case studies, NRS established a new project in the Midwest to investigate 1) How family forest owner participation in a carbon market trading program varies with different carbon sequestration compensation levels; and 2) How willingness to participate varies with owner, forest land tract, and carbon market trading program characteristics. Also in collaboration with scientists at the Pacific Northwest Station, NRS contributed to a study of policy tools for climate change mitigation in the forestry sector and their effects on the agricultural sector. In collaboration with the western Stations, NRS began an eastern expansion of the Climate Change Resource Center,[11] a reference Website for resource managers and decisionmakers who need information and tools to address climate change in planning and project implementation. NRS is planning several science delivery mechanisms associated with this research, including improvements to decision-support tools; participation in assessments of land management potentials for mitigation; and scientific exchange with other countries.

Impact on Management or Policy

The main impact of this research will be better decisions by landowners and land managers about how to sustain forest ecosystem services over the long term, as well as how to engage in market opportunities which support the protection of ecosystem services. At the same time,

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[11]http://www.fs.fed.us/ccrc/

there is potential for improved response to policies and programs for managing climate change, which will improve the ability of the United States to meet performance goals under global treaties. NRS research will inform communities of people about effective and efficient ways to adapt land use and management to possible changes in climate and related disturbance regimes.

Recent Publications (most of this research is getting under way in FY10)

Bosworth, Dale; Birdsey, Richard; Joyce, Linda; Millar, Constance. 2007. **Climate change and the nation's forests: Challenges and opportunities.** Journal of Forestry. 106(4): 214-221.

Frumhoff, P.C.; McCarthy, J.J.; Melillo, J.M.; Moser, S.C.; Wuebbles, D.J. 2007. **Confronting climate change in the U.S. Northeast: science, impacts, and solutions.** Synthesis report of the Northeast climate impacts assessment (NECIA): 1-146.

Appendix 3
STATUS REPORT FOR NRS PROJECTS INITIATED WITH INCREASED FUNDING IN FY 2009

This section reports project-by-project accomplishments of the NRS from the accumulated increase of $1.189 million provided to the NRS in FY 2009, plus accomplishments related to the additional $418,000 received in FY 2009 to address national priorities (see Table 6, page 17).

Carbon Cycle Science

Improve Monitoring at Experimental Forests and National Forests
(David Hollinger, principal investigator)

NRS is using climate towers to measure the movement of CO_2 in and out of ecosystems to learn more about the functioning of the carbon cycle and how ecosystems can be managed to increase carbon sequestration. Scientists are analyzing how to convert a series of flux stations in the region into a cohesive network that provides real-time data to understand how a changing climate will impact forest carbon cycling and sequestration. In FY 2009, NRS re-started the tower at Willow Creek in the Chequamegon-Nicolet National Forest; upgraded meteorological equipment to NOAA standards at most towers; and began testing carbon isotope analyzers to enable separation of CO_2 measurements between fossil fuel sources and vegetation sources.[12]

National Soil Carbon Network (NSCN) and Improved Soil Carbon Modeling
(Christopher Swanston, principal investigator)

The Forest Service, along with other federal agencies, is providing funding and planning efforts for the NSCN. The NSCN seeks to improve understanding of carbon dynamics in soils across the United States. In FY 2009 we continued to develop the network organization in support of projects to create high-resolution, large-scale soil carbon turnover and risk databases and maps. NRS organized oral and poster sessions on landscape-scale soil carbon turnover at American Geophysical Union 2008 fall meeting. NRS initiated collaboration with Lawrence Berkeley National Laboratory computing lab to build database infrastructure and analysis environment for network database; engaged U.S. Geological Survey/University of Alaska researchers in effort. NRS obtained supplemental grants of approximately $400,000 for data management and network coordination, and is advertising to fill a post-doctoral position.

Inventory and Monitoring

Monitoring of Climate Change Impacts on Experimental Forests
(Brian Palik, principal investigator)

The objectives of this project are to establish an efficient long-term monitoring protocol for repeated measurements to quantify tree establishment, growth, and mortality; identify a network of monitoring plots on experimental forests; and use dendrochronological methods to estimate establishment, growth, and mortality from the recent past. In FY 2009, NRS collaborated with the Southern Research Station (SRS) to integrate the forest dynamics monitoring with advanced methods for watershed monitoring being developed in the South. Project scientists developed an initial draft of a monitoring protocol that will be field tested in 2010. The current plan is to implement the new protocol within one study on each of five Experimental Forests: three hardwood (Argonne, Massabesic, Marcell) and two conifer (Cutfoot, Penobscot). Moreover, in collaboration with SRS partners, the protocol will be implemented at a study at the Coweeta Hydrologic Laboratory. Additionally, collaborators at SRS are providing protocols and equipment to instrument a single plot for remotely acquired, continuously monitored ecophysiological and environmental measurements.

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[12]http://www.nrs.fs.fed.us/disturbance/climate_change/flux_towers/

What Is the Best Protocol for Carbon Inventory of Forest Lands and Rangelands? NATIONAL PROJECT
(Dennis May, principal investigator)

The goal of this project is to improve the official estimates for forest and products carbon and other greenhouse gas (GHG) emissions developed for the U.S. EPA and the United States to meet requirements of the United Nations Framework Convention on Climate Change. The peer-reviewed and published methodologies also need to produce consistent estimates for other similar policy-related needs. Research on methods to characterize uncertainty is also needed. Tool development will make estimates more easily accessible for users to make customizable output and information. Previous versions of these estimates have been used in international negotiations by the United States, and the Intergovernmental Panel on Climate Change (IPCC) GHG inventories impact virtually all accounting systems. Substantial progress has been made. The most recent statistics published by U.S. EPA include more complete accounting for emissions from wildfire and better characterization of the uncertainty of estimates. As the U.S. forest inventory has evolved to annual data collection, new methods have been employed to make the estimates reported to EPA more current and to make them reflect interannual variability better.

Carbon Management

A Full Life-cycle Carbon Calculator for Forest Landowners and Policy Makers in the Northeast
(Mark Twery, principal investigator)

This work aims to provide a suite of GHG accounting software tools for forest managers to calibrate and calculate forest and forest product carbon (C) dynamics as well as forest-sector emissions (harvest, transport, manufacturing) as a function of stand dynamics and management projected with the Forest Service Forest Vegetation Simulator. Efforts will be actively integrated with ongoing forest C accounting research and software development in Canada and the United States, including existing decision-support models such as NED and LMS. Full accounting for carbon in harvested wood products and the substitution effects when using wood instead of other materials is essential for making management decisions for greenhouse gas mitigation. Progress to date has involved working closely with the Pacific Northwest Research Station to coordinate develop of eastern and western versions of forest carbon calculators with specific attention to the role of wood products and substitution of wood products for other materials.

Carbon Sequestration Potential of Poplar Energy Crops at regional scales
(Ronald Zalesny, Jr., principal investigator)

The objectives are: 1) merging knowledge of poplar biology with large-scale spatial analysis to predefine zones of potential plant adaptation that are ecologically and economically feasible across the landscape (SITING project); and 2) investigating the impact of fine woody debris removal on nutrient availability and above- and belowground community assemblages on rich soils under regenerating northern hardwood stands (BIOMASS project). The current collaboration between the U.S. Forest Service, Institute for Applied Ecosystem Studies (NRS RWU-13) and Iowa State University, Department of Natural Resource Ecology and Management, will build upon these existing studies to move closer to identifying suitable energy feedstocks in the Midwest. In FY 2009 wood chips were obtained from the Michigan State University, Upper Peninsula Tree Improvement Center (UPTIC) in Escanaba, Michigan, to begin preliminary testing during summer 2009, 10 clones were selected for testing from sites in Michigan and Iowa, selection of additional genotypes from Wisconsin was started (to be finalized during spring 2010), and potential sites in Minnesota were identified where similar genotypes can be evaluated. NRS conducted preliminary sampling during August 2009 to develop full-scale sampling methodologies. Trees were harvested during September and October 2009 at UPTIC as well as at the Iowa State University, Moore Lower Reactor Research Farm, Ames, IA.

Advancing the COLE Web Tool for Potential U.S. Forest Carbon Legislated Needs
(Linda Heath, principal investigator)

COLE is the principal Forest Service tool for supporting online forest carbon estimation by many users. New funding has allowed for continued advancements in capabilities and use of the most current inventory data. COLE, COLE-Lite and COLE-EZ have been updated to use the new FIADB4 database. This includes incorporating the new biomass estimates in FIADB4, which are based on the component ratio method. GCOLE, a new version of COLE, is now available to users. GCOLE has all of the capabilities of COLE, but it also has additional capabilities made possible by its Google Maps interface. Users can select data by states, counties, or circles. There are also several GIS layers available to enhance the user experience, such as a county boundary layer. GCOLE will be the platform for adding new capabilities going forward, and COLE will gradually be phased out.

Sustaining Forests under a Changing Climate: Strategic Decision Support for Mitigating Climate Change (Partnership between Forest Service and Princeton University)
NATIONAL PROJECT
(Richard Birdsey and Yude Pan, principal investigators)

This partnership develops advanced forest dynamics and climate models to assist land managers in making landscape-scale strategic plans for carbon management under a changing climate in North America, and to improve the land-atmosphere-ocean model system of the Geophysical Fluid Dynamics Laboratory (GFDL—a NOAA facility at Princeton) to support development of climate change policy. NRS and collaborators are developing data assimilation and modeling methods using FIA data as a foundation, to track and project the magnitude and causes of carbon sinks on the land, in the context of monitoring requirements of international greenhouse gas treaties. FY 2009 accomplishments included 1) Initiated a memorandum of understanding and cooperative research agreement; 2) Hired a post-doctoral scientist to focus on improving a forest dynamics model that can link to both forest management and the global carbon cycle; 3) Initiated U.S. - Mexico collaboration to establish a monitoring baseline, improving forest management and forest dynamics modeling, and assisting communities; 4) received a NASA Grant for a proposal titled Sustaining *U.S. Forests under a Changing Climate: A Management Strategy Integrating Impacts of Disturbances and Climate on Carbon Sequestration and Biofuels*. These funds will be used to hire a post-doctoral scientist; 5) Initiated a global forest carbon analysis in collaboration with Peking University and other research institutions around the world; 6) Initiated the U.S. National Forest Mitigation Assessment; and 7) started the Chequamegon-Nicolet National Forest Mitigation Assessment as part of the "Model Forest" Climate Change Response Framework.

PRESTO-Product Estimation Tool-Online. Phase 1-Scoping and design of a harvested wood products online carbon calculation tool
(Coeli Hoover, principal investigator)

Estimates of carbon in harvested wood products are particularly challenging to produce, yet wood products are an important variable in the analysis of tradeoffs between management objectives. The need exists for a stand-alone harvested wood products carbon calculator that will enable managers to provide harvest volumes and obtain estimates of carbon in harvested wood according to the 1605b methods. Product pools that will be estimated include: products in use, products in landfills, wood burned for energy, and emissions. In FY 2010, the design team solicited input from potential users and created a list of design considerations, which included flexible input formats, ability to run the program in simple and advanced modes to accommodate a variety of users, and a choice of yearly or 100 year average outputs. ESSA has prepared a preliminary design report that outlines the purpose, structure, and basic design of the tool, and is currently developing a limited functionality prototype that will be available over the internet.

The Effects of Landscape Disturbance and Restoration on Carbon Cycles: Modeling forest ecosystem changes resulting from surface mining for coal
(Mary Ann Fajvan, principal investigator)

The objective is to assess the impact of mountaintop mining on ecosystem carbon stocks on the Coal River watershed in southern West Virginia and to assess restoration and protection opportunities. The approach is to develop disturbance impact models for a smaller sub-watershed in the area. The sub-watershed will serve as a case study for testing the feasibility of integrating currently available GIS data layers, remote sensing, and existing data on disturbance/restoration impacts on carbon stocks to: 1) Identify specific areas and ecosystems that have been depleted of carbon stocks; 2) Calculate the reduction relative to a previous condition; and 3) Calculate the expected restoration impacts. In FY 2009, a map of surface mining permits was produced within the sub-watersheds for analysis and, incorporation of available FIA plot inventory data was begun to improve our estimate of current forest biomass. Project scientists worked with NASA to explore use of North American Forest Dynamics (NAFD) Landsat products, which are useful to the study because developing a sound understanding of forest disturbance and regrowth will improve knowledge of the contemporary North American carbon cycle.

Validating and Expanding the Carbon Accounting Toolkit for Forest Managers
(Coeli Hoover, principal investigator)

The purpose of this joint project is to improve operational estimates of the carbon content of forests and wood products for forest managers, and to develop outreach materials in support of those efforts. The project involves four major components: 1) Add the capacity to estimate carbon in live tree biomass to the SILVAH and NED decision support tools; 2) Implement harvested wood product accounting in NED and SILVAH; 3) Validate FVS carbon reporting for all variants; validate the added carbon reporting capability in NED and SILVAH; 4) Compare of live biomass and harvested wood products estimates between decision support tools. In consultation with NRS cooperators, scientists developed a tentative work plan consistent with the initial work outline.

How do Private Landowners Respond to Different Mechanisms that Encourage GHG Reductions from Land Management? NATIONAL PROJECT
(Stephanie Snyder, principal investigator)

In FY 2009, NRS collaborated with scientists at the Pacific Northwest Research Station on studies of forest and range management carbon-offset projects on private lands in the U.S and policy tools for climate change mitigation in the forestry sector and their effects on the agricultural sector. These case studies highlighted some interesting findings relative to motivations to undertake offset projects, the types of activities landowners are pursuing while enrolled in offset projects, challenges in developing offset projects, lessons learned, and suggestions for improvements to the process of enrolling in forest carbon offset program.

Atmospheric Deposition and Watersheds

Modeling and Forecasting of Complex Effects of Land Use, Climate, and Air Pollution
(Yude Pan, principal investigator)

NRS scientists and collaborators are developing advanced ecosystem modeling and forecasting for forested watersheds in Region 9. The goals of this initiative are to (1) Quantify effects of climate variability and trends, altered atmospheric composition, natural disturbances, and land use change on structure and function of forest ecosystems, and (2) Quantify effects of forests in a watershed on the microscale stream environments and aquatic biota and quantify carbon and nitrogen losses to the surface waters. In FY 2009, NRS initiated a cooperative research agreement with University of Pennsylvania and finished compiling data collected over several

years in the Delaware River Basin, including FIA data, the data from the intensive study sites, dataset of climate, soil, atmospheric N deposition and ozone, U.S. Geologic Survey (USGS) gauge station data, the USGS field data, and previous modeling results.

Effects of Climate and Air Quality on Ecosystems

Use of Long-term Experimental Forest Provenance Trials for Selection of Future Forests: Tools to predict forest adaptation to climate change
(Nick Skowronski, principal investigator)

The objective is to determine what provenances will be suitable for restoration after dieback or disturbances and to provide a proof-of-concept study and framework for future long-term provenance tests in the Forest Service's Experimental Forest network. The methodology will be implemented in a 35-yr-old provenance trial where pitch pine seed sources from a latitudinal gradient from Canada to Georgia have been planted. NRS will measure the trends in annual increment and earlywood/latewood ratios to determine which seed sources are suitable for restoration and recommend pitch pine provenances for the Pinelands National Reserve. In FY 2009, NRS established a new research joint venture agreement (RJVA) and study plan with Dr. Neil Pederson, Eastern Kentucky University, for the coring of 1440 trees, planned for spring 2010. In addition, project personnel re-marked plots, mapped and retagged trees, updated software for in-house WinDendro analysis system for analysis of tree ring density, and negotiated with Dr. Ed Cook, Lamont-Doherty Earth Observatory, for tree-core analysis work in 2010.

Improve Understanding of Climate Change and Disturbance Impacts on Wildlife
(Frank Thompson, principal investigator)

The objective is to predict changes in tree and wildlife species in the Ozark Highlands over the next 200 years. The approach is to link LANDIS, a dynamic landscape model, with climate predictions and wildlife models to consider the effects of climate, forest management, disturbance, and succession through various scenarios to highlight the sensitivity of landscapes and wildlife to these factors. In FY 2009, NRS scientists conducted simulations to evaluate sensitivity of LANDIS to model changes in species composition based on shifts in species establishment coefficients (hypothesized as an effect of climates change) with and without increased mortality or management. Several options were investigated for modifying vegetation life history parameters in LANDIS to simulate effects of climate change.

Regeneration of Model Aspen Ecosystems in Elevated CO_2 and O_3 The Northern Forest Ecosystem
(Mark Kubiske, principal investigator)

Aspen FACE is a multidisciplinary study to assess the effects of increasing tropospheric ozone and CO_2 levels on the structure and function of forest ecosystems in the Great North Woods. Located in northern Wisconsin, the project is designed to determine the effects of ozone and CO_2 on many ecosystem attributes, including growth, leaf development, root characteristics, and soil carbon. In FY 2009, NRS began the final biomass harvest to complete the first decade experiment funded in large part by the U.S. DOE. A second ecosystem experiment will begin in FY 2010.[13]

Impacts of Future Land Cover Changes on Global Climate
(Warren Heilman, principal investigator)

NRS is examining how surface temperatures, atmospheric moisture, and other climate variables will react to potential changes in forest cover associated with afforestation efforts, using the National Center for Atmospheric Research Community Climate System Model (Version 3) and

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[13]http://aspenface.mtu.edu/; http://www.ncrs.fs.fed.us/4401/focus/face/

the computing environment established in the Eastern Area Modeling Consortium. Research will integrate regional-scale measurements and models of carbon, water, and energy exchanges between the land surface and the atmosphere with models simulating the regional and global climate systems. In FY 2009, project scientists performed global climate simulations using the Community Climate System Model - Version 3 and examined the results to determine the sensitivity of the predicted climate fields to broad scale but modest changes in albedo for all tree-dominated plant functional types.

Montane Birds and Habitats as Sentinels of Climate Change
(David King, principal investigator)

NRS is using long-term survey data on bird abundance to document shifts in abundance and nesting phenology over an elevational gradient on the White Mountain National Forest. These analyses will provide important insight into the response of bird communities to a changing climate in surrounding lowland areas because the elevational gradient represents a gradient of climactic conditions predicted for the entire region under various climate change scenarios. The high elevation bird monitoring dataset has been obtained from the White Mountain National Forest. Preliminary analysis indicates that consistent with predictions, bird species characteristic of northern hardwoods forests have shifted their distribution upward in elevation since 1992. Surprisingly, birds characteristic of montane spruce-fir forest have actually shifted downwards in elevation over this period. Future work will be directed toward incorporating precipitation into statistical models, as well as nesting phenology and reproductive success.

The Houghton Mesocosm Facility: Parameterizing Models of Feedbacks between Peatlands and Climate Change
(Erik Lilleskov, principal investigator)

NRS scientists are using the Houghton Mesocosm Facility to develop response functions of sphagnum peatland carbon cycling and trace gas emissions to climate change. Peatlands are a large terrestrial carbon stock and are very vulnerable to the effects of climate change. In FY 2009 NRS completed much of the instrumentation of the mesocosm: installed an integrated monitoring/control system using state-of-the-art networks of sensors, dataloggers and datalogging software, and purchased sensors sufficient to instrument 16 of the mesocosm bins for the peat manipulation experiment. An initial test peat monolith, approximately 1 m^3, has been successfully harvested, and the location for harvest of the full complement of peat monoliths for the initial experiment has been identified.

Climate Change Tree and Bird Atlases
(Louis Iverson and Anantha Prasad, principal investigators)

NRS scientists have developed a Climate Change Tree Atlas and a Climate Change Bird Atlas. These atlases examine current distributions and model future climate habitats for 134 tree species and 150 bird species. In FY 2009, NRS scientists began to modify the SHIFT program to enhance its accuracy and processing speed using advanced algorithms and computational techniques. SHIFT is a spatially explicit cellular model that is used to calculate the colonization probabilities of tree species based on habitat availability and abundance in each cell (presently, 1km). SHIFT is used in combination with our empirical-statistical model, DISTRIB, to assess the colonization potentials of tree species more realistically under current fragmented landscapes and also under future species abundances according several climate projections (Global Circulation Models). NRS has made substantial progress toward this end by achieving a tremendous increase in processing speed, opening up exciting avenues for further research in exploring the effect of fragmented habitats on tree species migration.[14]

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[14]http://www.nrs.fs.fed.us/atlas/

Social Impacts and Adaptation

Sustainable Forest Management in an Uncertain Climate Future: Eastern Region "Model Forests"

(Chris Swanston, principal investigator)

NRS is working with the EasternRegion and Northeastern Area to help the region's foresters understand climate change effects and develop adaptation strategies. This work will consider efforts that both adapt forests to changing conditions and mitigate greenhouse gas emissions. The Chequamegon-Nicolet National Forest (CNNF) has been designated as a climate change "model forest for landscape management." NRS and the Eastern Region are currently developing a framework to integrate scientific and management activities in response to climate change while fostering dialogue about climate change effects and potential responses across shared landscapes with private forest landowners and other partners and stakeholders. Major activities in FY 2009 included workshops with the CNNF to initiate the model forest concept, initiation of mitigation and adaptation assessments, and planning for a science needs workshop planned for FY 2010.

What are the Climate Change Impacts (economic, bioenergy, private/public forests) on the Nation's Forest and Rangelands? NATIONAL PROJECT

(Robert Haight, principal investigator)

The goals of this work are to collaborate on a project to assess impacts of climate change mitigation policies in the forest sector, review literature on social aspects of climate change mitigation and adaptation in the forest sector, and contribute to the writing of research strategies at the research work unit and Station levels. Progress to date has involved analysis of policy tools for climate change mitigation in the forestry sector and their effects on the agricultural sector, with specific reference to the Midwestern U.S. and the potential impacts of forest mitigation on cropland.

What Is the Capability of National Forests to Mitigate and Adapt to Climate Change under Current and Future Management Trends? NATIONAL PROJECT

(Richard Birdsey, principal investigator)

NRS received funding from the Forest Service National Office to lead a national climate change issue titled "What is the capability of National Forests to mitigate and adapt to climate change under current and future forest management trends?" In collaboration with the Pinchot Institute, the partners conducted a workshop in January 2010 to develop the "Protocols for Assessing the Impacts of U.S. National Forest Management on Carbon Stocks." This will be followed by a concerted national effort to implement the assessment in future years.

How Will Wildfire Risks and Effects (C emissions) Change under Different Climate and Management Scenarios? NATIONAL PROJECT

(Chris Swanston, principal investigator)

Funds for this project were used to address fire information needs as described in the next project on science delivery.

How will the Forest Service Deliver Its Climate Change Information and Web Applications? NATIONAL PROJECT

(Chris Swanston, principal investigator)

The current climate change resource center (CCRC)[15] was designed to deliver relevant content and tools to natural resource managers and landowners. However, it has become a comprehensive Forest Service resource on ecosystem response and adaptation to climate

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[15]www.fs.fed.us/ccrc

change. Expanded development of this site will address both national questions by helping to more effectively deliver information and data regarding the effects of climate change on ecosystems (including fire), and providing a nexus for discussion of the options for Forest Service management responses. The existing CCRC features examples of western forest responses to climate change and associated research developed by the Rocky Mountain Research Station, Pacific Southwest Research Station, Pacific Northwest Research Station, and the Western Wildland Environmental Threat Assessment Center , with input from western regional offices. To gain a complete national perspective, the Southern Research Station , the Northern Research Station (NRS), the Forest Products Lab, the International Institute of Tropical Forestry, and the Eastern Forest Environmental Threat Assessment Center—with input from the Eastern and Southern Regions and Northeastern Area—propose to expand the CCRC scope to include eastern United States climate change research and resources. This CCRC expansion will provide perspectives from across the United States on forest responses to climate change, and Forest Service efforts to study these responses and adapt to the changing climate. Eastern and western resource managers and decisionmakers will have an increasingly relevant and effective tool to help answer many regional and national forest-based climate change questions. As a result of this effort, the CCRC now offers summaries of climate change research being conducted at the Northern and Southern Research Stations, new tools for land managers relevant to the eastern states, and eastern case studies on National Forest responses to climate change.

APPENDIX 4

NRS BUDGET DETAIL BY PROJECT AND FUNDING YEAR

Title, SCOPE/Term	FY 2009 Funding ($1.607 million)	FY 2010 Allocation A ($390,000)	FY 2010 Allocation B ($799,000)	FY 2010 Increase ($2.7 million)	Total FY 2010 Funding	Comments
CARBON CYCLE SCIENCE	**$265,000**				**$985,000**	
Improve monitoring at experimental forests and national forests. EASTWIDE/100% long term	$100,000	$70,000	$35,000		$105,000	Coordinate with new FY 2010 funding allocation; supports Willow Creek, Baltimore, other NRS sites.
National soil carbon network and improving soil carbon modeling. NATIONAL/100% long term	$80,000		$80,000		$80,000	Need to maintain momentum. This is core funding for data management and coordination.
Carbon Cycle Science. NATIONAL/60% long term; 30% medium term	$85,000			$800,000	$800,000	Details of allocation attached. See Table 4 Includes $100,000 to PNW, $100,000 to SRS, $100,000 to RMRS, and $120,000 to PSW.
INVENTORY AND MONITORING	**$255,000**				**$600,000**	
Monitoring of climate change impacts on experimental forests across the northern forest region. EASTWIDE/100% long term	$80,000		$100,000		$100,000	Good collaboration with SRS. Need to integrate with Project 1 (review site selection).
Improve official estimates and carbon accounting tools. NATIONAL/60% long term; 30% medium term	$175,000			$500,000	$500,000	Includes $40,000 to PNW.

APPENDIX 4. CONTINUED

Title, SCOPE/term	FY 2009 Funding ($1.607 million)	FY 2010 Allocation A ($390,000)	FY 2010 Allocation B ($799,000)	FY 2010 Increase ($2.7 million)	Total FY 2010 Funding	Comments
CARBON MANAGEMENT	**$359,500**				**$269,500**	
A full life-cycle carbon calculator for forest landowners and policy makers in the Northeast. REGIONAL/100% medium term	$55,000	$55,000			$55,000	Coordinate with new FY 2010 funding. Second-year funding needed to complete project.
Carbon sequestration potential of poplar energy crops at regional scales. REGIONAL/100% medium term	$30,000		$30,000		$30,000	Made good progress and good leverage with other funds.
Advancing the COLE web tool for potential U.S. forest carbon legislated needs. NATIONAL	$75,000					This funding has been replaced with allocation of new FY 2010 funds (see last item under "Inventory and Monitoring").
Sustaining U.S. Forests under a changing climate: FS/Princeton University climate change partnership. NATIONAL/100% long term	$110,000	$110,000			$110,000	This funds the base post-doc coordinator position at Princeton.
PRESTO-Product Estimation Tool-Online. Phase 1-Scoping and design of a harvested wood products online carbon calculation tool. NATIONAL	$15,000					This funding has been replaced with allocation of new FY 2010 funds (see last item under "Inventory and Monitoring").
The effects of landscape disturbance and restoration on carbon cycles: Modeling forest ecosystem changes resulting from surface mining for coal. REGIONAL/100% medium term	$30,000		$30,000		$30,000	Making good progress. Did not request additional funds.
Validating and expanding the carbon accounting toolkit for forest managers. REGIONAL/100% medium term	$44,500		$44,500		$44,500	Good progress—additional funds needed to complete the work as planned.

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Title, SCOPE/Term	FY 2009 Funding ($1.607 million)	FY 2010 Allocation A ($390,000)	FY 2010 Allocation B ($799,000)	FY 2010 Increase ($2.7 million)	Total FY 2010 Funding	Comments
EFFECTS OF CLIMATE CHANGE AND AIR QUALITY	**$455,500**				**$1,532,000**	
Use of long term experimental forest provenance trials for selection of future forests. REGIONAL/100% medium term	$75,000		$75,000		$75,000	Made good progress getting set up for dendro-chronological analysis.
Improve understanding of climate change and disturbance impacts on wildlife. REGIONAL/100% medium term	$147,500	$105,000			$105,000	Making good progress.
Regeneration of model aspen ecosystems in elevated CO_2 and O_3. REGIONAL/100% long term	$35,000			$1,100,000	$1,100,000	Finishing up work from Phase 1 and transitioning to fully funded Phase 2.
Regional studies of the effects of land use and forest management on the climate system. REGIONAL/100% medium term	$50,000		$75,000		$75,000	Making good progress with simulations and products; increased funds to upgrade computer cluster to reduce limitation of processing speed.
Montane birds and habitats as sentinels of climate change. REGIONAL/100% medium term	$18,000		$25,000		$25,000	Making good progress in developing analytical approach.
Modeling tree species response to migrating habitats. EASTWIDE/100% long term	$50,000		$30,000		$30,000	Requested reduced funding. Making good progress.
Using the Houghton mesocosm facility for climate change research: feedbacks between peatlands and climate change. REGIONAL/100% long term	$80,000		$122,000		$122,000	Facility is poised to make excellent progress with first experiment in FY 2010. Requested additional funding.

Appendix 4. Continued

Title, SCOPE/Term	FY 2009 Funding ($1.607 million)	FY 2010 Allocation A ($390,000)	FY 2010 Allocation B ($799,000)	FY 2010 Increase ($2.7 million)	Total FY 2010 Funding	Comments
ATMOSPHERIC DEPOSITION AND WATERSHEDS	**$40,000**				**$80,000**	
Modeling and forecasting of complex effects of land use, climate, and air pollution. REGIONAL/100% medium term	$40,000		$80,000		$80,000	All resources, personnel, and data sets in place for implementation in 2010. New funds needed for full post-doc salary.
SOCIAL IMPACTS AND ADAPTATION	**$232,000**				**$374,000**	
Sustainable forest management in an uncertain climate future: eastern region "Model Forests". EASTWIDE/100% long term	$75,000	$50,000			$50,000	Funds needed to support conversion of MTU position to FS. FY 2009 included $25,000 for fire science from national pool of funds.
Modeling support for NFS-R9 model forests. EASTWIDE/100% long term	$24,000		$24,000		$24,000	Needed to continue support and development of models.
Overcoming social and economic barriers to climate change adaptation and mitigation. NATIONAL/60% Long-term; 30% medium term	$133,000			$300,000	$300,000	Details of allocation attached. Includes $60,000 to PNW.
RESERVE TO BE ALLOCATED						
Reserve for additional short-term needs. EASTWIDE/100% short term			$48,500		$48,500	To be used in consultation with Executive Team to address short-term needs that arise during the FY.
TOTAL	**$1,607,000**	**$390,000**	**$799,000**	**$2,700,000**	**$3,889,000**	

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