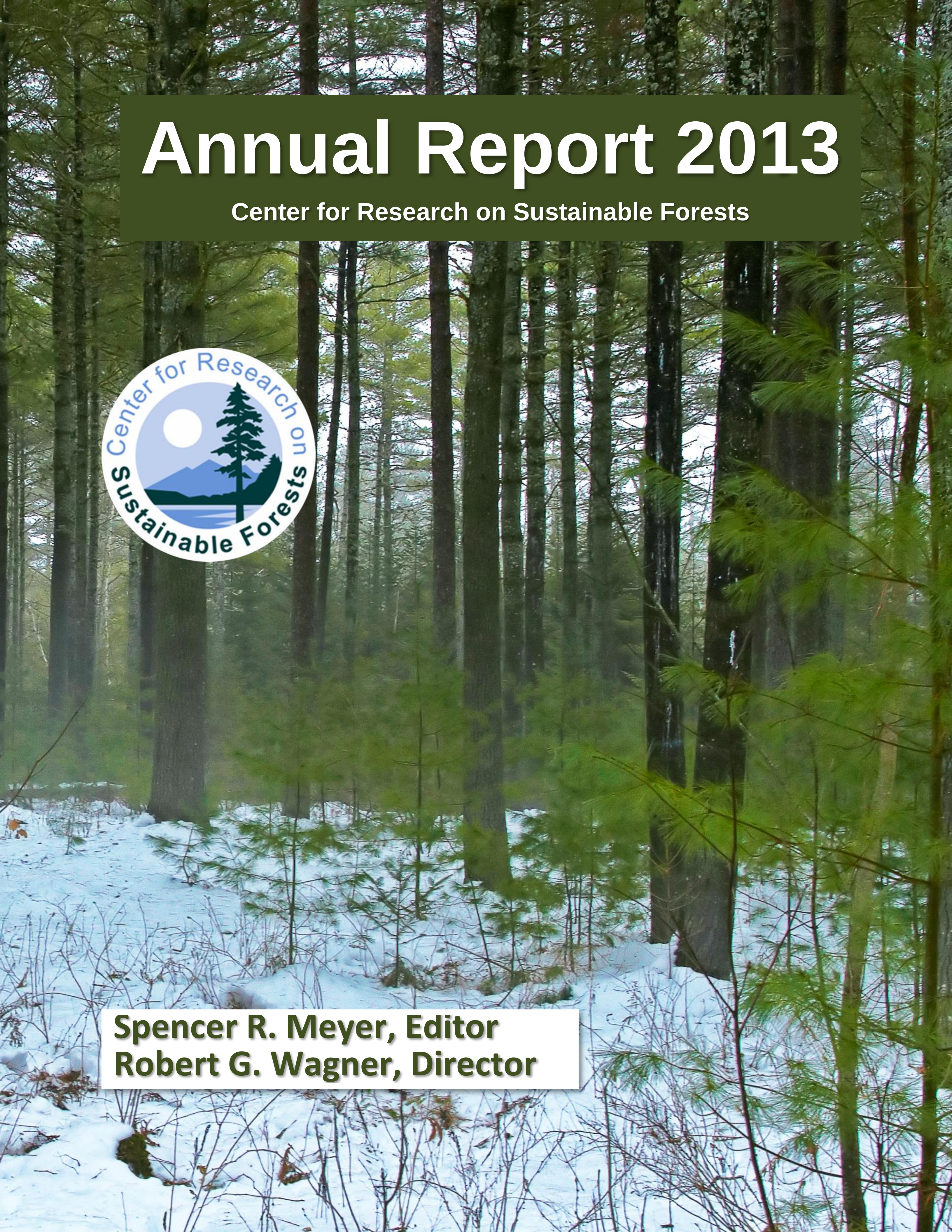
Annual Report 2013

Center for Research on Sustainable Forests



Spencer R. Meyer, Editor
Robert G. Wagner, Director

About the Center

The Center for Research on Sustainable Forests (CRSF) was founded in 2006 to build on a rich history of leading forest research and to enhance our understanding of Maine's forest resources in an increasingly complex world. CRSF brings together the natural and social sciences with an appreciation for the importance of the relationship between people and our ecosystems. We conduct research and inform stakeholders about how to balance the wise-use of our resources while conserving our natural world for future generations.

Our mission is to *conduct and promote leading interdisciplinary research on issues affecting the management and sustainability of northern forest ecosystems and Maine's forest-based economy.*

Center for Research on Sustainable Forests
University of Maine
5755 Nutting Hall
Orono, Maine 04469-5755
Tel. 207.581.3794

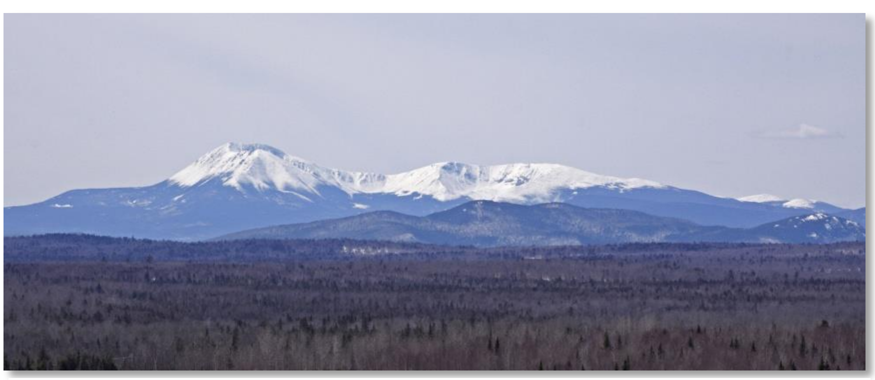
crsf.umaine.edu

Citation

Meyer, S.R. (Ed.) 2013. Center for Research on Sustainable Forests: 2013 Annual Report. University of Maine, Orono, Maine. 145 p.

Cover photo: *Snowy Forest* by Pamela Wells

Contents



Mount Katahdin - photo by Pamela Wells

Director's Report

The Center for Research on Sustainable Forests (CRSF) had another productive year during 2012-13. **Dr. Brian Roth** along with several scientists and over 30 member organizations through the Cooperative Forestry Research Unit (CFRU) did a great job on a variety of important issues related to Maine's commercial forestlands. **Dr. Jessica Leahy** and her graduate students continued leading a strong research effort focused on Maine's family forests.

Dr. Rob Lilieholm and **Spencer Meyer** did a great job illuminating a number of new trends related to Maine's conservation forestlands. **Dr. Mohammad Bataineh** completed a wonderful analysis in collaboration with the USFS Northern Research Station and CFRU on 40-year outcome of silvicultural investments in young spruce-fir stands. **Kae Cooney** continued doing a great job managing the administrative issues of CRSF and NSRC. We also welcomed **Cindy Smith** as the new Administrative Assistant for the CFRU. The overall success of the CRSF this year is also due in large measure to the hard work of many scientists, graduate students, and summer technicians that worked on CRSF research projects. Their hard work and accomplishments are described in the following report.

Together, all of the scientists associated with the CRSF brought a total of $1.85 million in outside revenue to support forest research in Maine and the northern forest. Of that, $1.36 million (or 73%) was spent directly on the research. The Maine Economic Improvement Fund (MEIF) provides base operating funds for the CRSF. The $144K investment by MEIF this year leveraged another $1.71 million from outside sources to support the CRSF mission; thus providing a 12:1 return. A hallmark of the success of the CRSF research effort is also measured by the 130 organizations that collaborated directly in the research presented in this report. Results from CRSF research were presented this year in 32 journal articles; 32 book chapters, theses, and research reports; and 130 presentations at conferences and meetings.

Finally, we want to extend a very special thanks to **Dr. Michael Eckardt**, UMaine's Vice President for Research. Mike is retiring this year after providing years of tremendous support to the forest research effort at UMaine. No program could have had a bigger champion for their efforts than we have had in Mike. He has a special connection to the forests of Maine and advocated for them through his position as Vice President for Research. As part of this commitment, Mike approved and financially supported the plan to develop the CRSF in 2006. We thank him for his vision and commitment, and wish him the best in his well-earned retirement.

Robert G. Wagner

Robert G. Wagner, CRSF

People

Leadership and Staff

Robert Wagner
Director

Jessica Leahy
Family Forest Program Leader

Rob Lilieholm
Conservation Lands Program Leader

Spencer Meyer
Associate Scientist for Forest Stewardship

Brian Roth
CFRU Associate Director

Mohammed Bataineh
CFRU Post-Doctoral Research Scientist

Kae Cooney
CRSF Administrative Assistant

Cynthia Smith
CFRU Administrative Assistant

Cooperating Scientists

Jeffrey Benjamin (CFRU)
Daniel Harrison (CFRU)
Robert Seymour (CFRU)
Aaron Weiskittel (CFRU)

Project Scientists

Thom Erdle, *Univ. of New Brunswick* (CFRU)
Gary Hawley, *Univ. of Vermont* (NSRC)
Chris Hennigar, *Univ. of New Brunswick* (CFRU)
Ted Howard, *Univ. of New Hampshire* (NSRC)
John Kershaw, *Univ. of New Brunswick* (CFRU)
Kasey Legaard (NSRC)
David MacLean, *Univ. of New Brunswick* (CFRU)
Andrew Nelson (NSRC, CFRU)
Ralph Nyland, *SUNY College of Environmental Science and Forestry* (NSRC)
Matthew Olson (NSRC, CFRU)
Ben Rice (NSRC, CFRU)
Steven Sader (NSRC)
Robert Seymour (NSRC)
Margaret Snell (Family Forests)
Crista Straub (Family Forests)
Aaron Weiskittel (NSRC)
Ronald Zalesny, *U.S. Forest Service* (NSRC)

Graduate Students

Patrick Clune (CFRU)
Steven Dunham (CFRU)
Patrick Hiesl (CFRU)
Michelle Johnson (SSI, Cons. Lands)
Spencer Meyer (SSI, Cons. Lands)
Andrew Nelson (CFRU)
Sheryn Olson (CFRU)
Michael Quartuch (SSI, Family Forests)
Ben Rice (CFRU)
Matthew Russell (CFRU)
Emily Silver (Family Forests)
Brittney Townsend (Family Forests)

Undergraduate Students

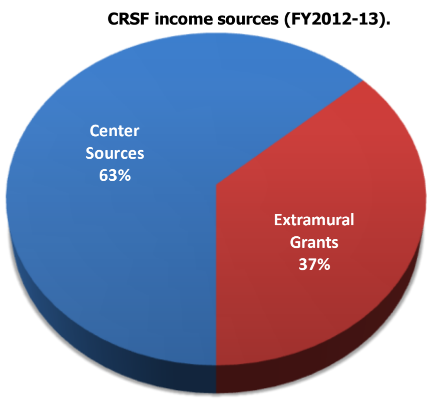
Laura Brehm (Family Forests)
Norah Bird (Family Forests)
Tynesha Davis (Family Forests
Sarah Peckenham (Family Forests)

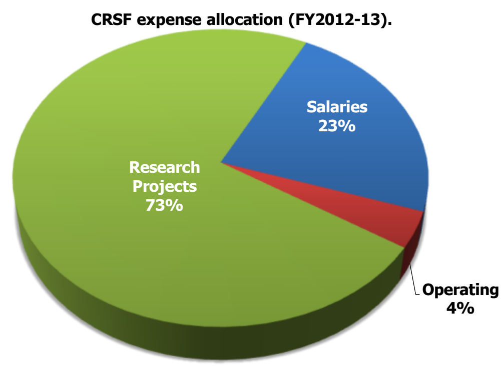
Financial Report

Income and expenses for the CRSF during FY2012-13 are shown in Table 1. Income supporting the center came from programs administered by or that support the general operations of the CRSF ($1,174,123), as well as extramural grants supporting specific research projects ($679,653) that were received by CRSF scientists from outside agencies. These extramural grants made up 37% of funding for the center and leveraged an additional 63% above CRSF's funding (Figure 1). Total funding of the CRSF for FY2012-13 was $1.85 million.

About 73% of the funding received by CRSF went directly to support research projects described in this report (Figure 1). The remaining 27% supported personnel for the salaries (23%) and operating expenses (4%) center. The proportion of total funding allocated to research projects among the four programs making up the CRSF is shown in Figure 1: Commercial Forests (31%), Family Forests (23%), Conservation Lands (22%), and research projects supported by the Northeastern States Research Cooperative and administered by the CRSF (24%).

A core source of financial support for the CRSF is provided by the Maine Economic Improvement Fund (MEIF). The $144,069 investment by MEIF helped leverage $1,030,054 from other CRSF sources and $679,653 in extramural grants for a total of leverage of $1,709,707, or a 11.9 multiplier from the MEIF investment.





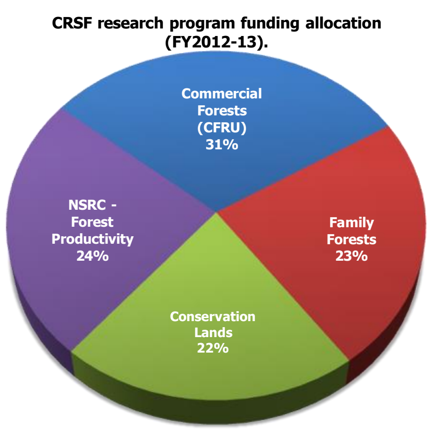


Figure 1. Income (top left) and expenses (top right) for the CRSF during FY 2012-13. CRSF funds were allocated relatively evenly to four different programs (bottom left).

Table 1. FY2012-13 budget for Center for Research on Sustainable Forests.

			Amount
INCOME			
Center Sources:			**Amount**
Cooperative Forestry Research Unit (CFRU)			$ 500,107
US Forest Service - Northeastern States Research Cooperative - Theme 3 (NSRC)			$ 414,571
Maine Economic Improvement Fund (MEIF)			$ 144,069
National Science Foundation - Center for Advanced Forestry Systems (CAFS)			$ 70,000
Maine Agriculture & Forest Experiment Station (MAFES)			$ 20,917
UMaine Munsungan Fund			$ 24,459
		Center Total	**$ 1,174,123**
Extramural Grants:			
National Science Foundation - Sustainability Solutions Initiative (SSI)			$ 388,115
US Forest Service - Northeastern States Research Cooperative - Theme 1 (NSRC)			$ 72,740
Small Woodland Owners of Maine (SWOAM)			$ 73,000
US Forest Service, Northern Research Station, Joint Venture Agreement (USDA-JVA)			$ 77,565
Colorado State University (CSU)			$ 19,903
Maine Economic Improvement Fund (MEIF)			$ 15,000
Forest Bioproducts Research Institute (FBRI)			$ 33,330
		Extramural Grant Total	**$ 679,653**
		Total Income	**$ 1,853,776**
ALLOCATION			
Salaries & Benefits:			
Director, Associate Director, Program Leaders, and Scientists			$ 372,906
Support staff			$ 48,481
		Salaries & Benefits Total	**$ 421,386**
Operating Expenses:			$ 73,692
		Salaries, Benefits, & Operating Total	**$ 495,078**
Research Projects:	**Funding Source**	**PI**	
Commercial Forests (CFRU):			
Improved Growth & Yield Models	NSF	Wagner & Weiskittel	$ 70,000
Commericial Thinning Research Network	CFRU	Wagner et al.	$ 55,877
Young Hardwood Silviculture Response G&Y Modeling	CFRU	Wagner et al.	$ 22,617
Machine Productivity and Cost	CFRU	Benjamin	$ 38,398
Austin Pond: Third Wave	CFRU	Wagner	$ 56,481
Extending the FVS to managed stands	CFRU	Weiskittel	$ 18,646
LiDAR for Forest Inventory	CFRU	Weiskittel	$ 29,848
Spruce Grouse Habitat in Northern Maine	CFRU	Harrison	$ 38,500
Long-term Monitoring of Snowshoe Hare	CFRU	Harrison	$ 55,212
Effects on Bird Communities	CFRU	Harrison	$ 28,964
		Commercial Forests Project Total	**$ 414,543**
Family Forests:			
Identifying Meaningful Incentives-Public Access/Private Lands	SWOAM	Leahy	$ 45,000
An Oral History Place Attachment Project	NSRC	Leahy	$ 37,740
A Long-Term Monitoring Program-Logging Industry Health	NSRC	Leahy	$ 25,000
Family Forest ForCAST Project	MEIF	Mann	$ 15,000
Maine Sustainability Science Initiative Yr 3	NSF/SSI	Benjamin	$ 115,210
Kennebec Woodland Owners Project	USDA	Leahy	$ 9,385
Resolving a critical question in predicting woody biomass supply	NSRC	Leahy	$ 10,000
Sustainable Energy Pathways: Integrated National Framework	NSF	Leahy	$ 33,330
Small Woodland Owner Research	SWOAM	Leahy	$ 28,000
		Family Forests Project Total	**$ 318,665**
Conservation Lands:			
Alternative Futures Modeling in Maine	NSF-SSI	Lilieholm	$ 232,905
Wildebeest Forage Acquisition in Fragmented Landscapes	CSU	Boone	$ 19,903
Maine Community Mapper	SSI	Meyer	$ 40,000
		Conservation Lands Project Total	**$ 292,808**
NSRC Theme 3:			
Regional Effects of Silviculture and Site Factors on Regeneration	NSRC	Bataineh	$ 74,861
Logging Businesses in Northern Forest	NSRC	Benjamin	$ 73,250
Impacts of Alternative Future Land Uses across Maine	NSRC	Meyer	$ 58,201
Nitrogen Deposition Processing Watershed Nitrogen Export	NSRC	Mineau	$ 78,216
Extending FVS to Intensively Managed Stands	NSRC	Wilson	$ 48,154
		NSRC Project Total	**$ 332,682**
		Research Project Total	**$ 1,358,698**
		Total Allocation	**$ 1,853,776**

Stakeholders

CRSF researchers strive to conduct not just cutting edge forest science, but also real-world, applied science about Maine's forests, forest-based businesses, and the public that supports them. We recognize that Maine is full of organizations that already represent the best interest of forest resources and that each fills its own niche. We build and foster relationships with these organizations and their people to achieve overlapping goals. Over the last year we have worked with the following partners:

Acadia National Park

African Wildlife Foundation

Andrews Timber Company

Appalachian Mountain Club
Baskahegan Corporation

Association of Consulting Foresters

ASU Landscape Ecology and Modeling Lab

Avery and Son Logging

Baxter State Park, Scientific Forest Management Area

BBC Land, LLC

Belfast Bay Watershed Coalition

Canopy Timberlands Maine, LLC

Casco Bay Estuary Partnership

City of South Portland

Clayton Lake Woodlands Holding, LLC

Colorado State University

Comstock Woodlands

Cumberland County Soil and Water Conservation District

DEP

Dirigo Timberlands

Downeast Lakes Land Trust

Downeast Research and Education Network

Downeast Salmon Federation

Elliotsville Plantation

EMC Holdings, LLC

Environmental Funders Network

Field Timberlands

Wild Thistle (photo Pamela Wells)

Finestkind Tree Farms

Forest Resources Association

Forest Society of Maine

Frenchman Bay Conservancy

Frontier Forest, LLC

Grand Staircase-Escalante National Monument

Hampden Academy

Harry H Melcher and Sons, Inc.

Harvard University
Headwaters Economics

Huber Engineered Woods, LLC

Interlocal Stormwater Working Group

International Livestock Research Institute

Stream Ferns (photo Pamela Wells)

Irving Woodlands, LLC
JD Hummel
JL Brochu
Katahdin Forest Management, LLC
Kennebec Land Trust
Kennebec Woodland Partnership
Kenya Wildlife Service
LandVest
Lincoln Institute of Land Policy
LURC/LUPS
Madden Timberlands
Maine Bureau of Parks and Lands
Maine Coast Heritage Trust
Maine Department of Agriculture, Conservation and Forestry
Maine Department of Agriculture, Conservation and Forestry
Maine Department of Inland Fisheries and Wildlife
Maine Division of Parks and Public Lands
Maine DOT
Maine Forest Products Council
Maine Forest Service
Maine Geological Survey
Maine Professional Guides Association
Maine Sea Grant
Maine Snowmobile Association
Maine Tree Foundation
Marine Estuary Research Institute
Michigan Tech
Mosquito, LLC
MPBN
New England Forestry Foundation
North Woods Maine, LLC
Northeast Master Logger Certification Program
Oakleafs Studios
Old Town Fuel and Fiber
Pelletier and Pelletier
Penobscot River Restoration Trust
Plum Creek Timber Company, Inc.
Precision Paving
Prentiss and Carlisle Company, Inc.
Quebec Ministry of Natural Resources
Quebec-Labrador Foundation
ReEnergy Holdings, LLC
Rejean Bernard
Robbins Lumber Company
S. W. Cole Engineering, Inc.
SAF/NAUFRP
SAPPI Fine Paper
Schoodic Education and Research Center
SeedTree
SeedTree Nepal
Seven Islands Land Company
Sewall Company.
Simorg North Forest, LLC

Small Woodland Owners Association of Maine

Snowshoe Timberlands, LLC

Society of American Foresters

St. John Timber, LLC

State Planning Office

Swiss National Science Foundation

Sylvan Timberlands, LLC

The Forestland Group, LLC

The Nature Conservancy

The Nature Trust of New Brunswick

Timbervest, LLC

Toledo Institute of Development and Environment (Belize)

Town of Topsham

Treeline

Trust to Conserve Northeast Forestlands

U.S. Forest Service

University of Maine, Cooperative Extension

University of Massachusetts – Amherst

University of Nairobi

University of New Brunswick

UPM Madison Paper

Upward Bound

USDA

USDA, Forest Service, Northern Research Station

USDA, Natural Resource Conservation Service

USDI BLM

USGS

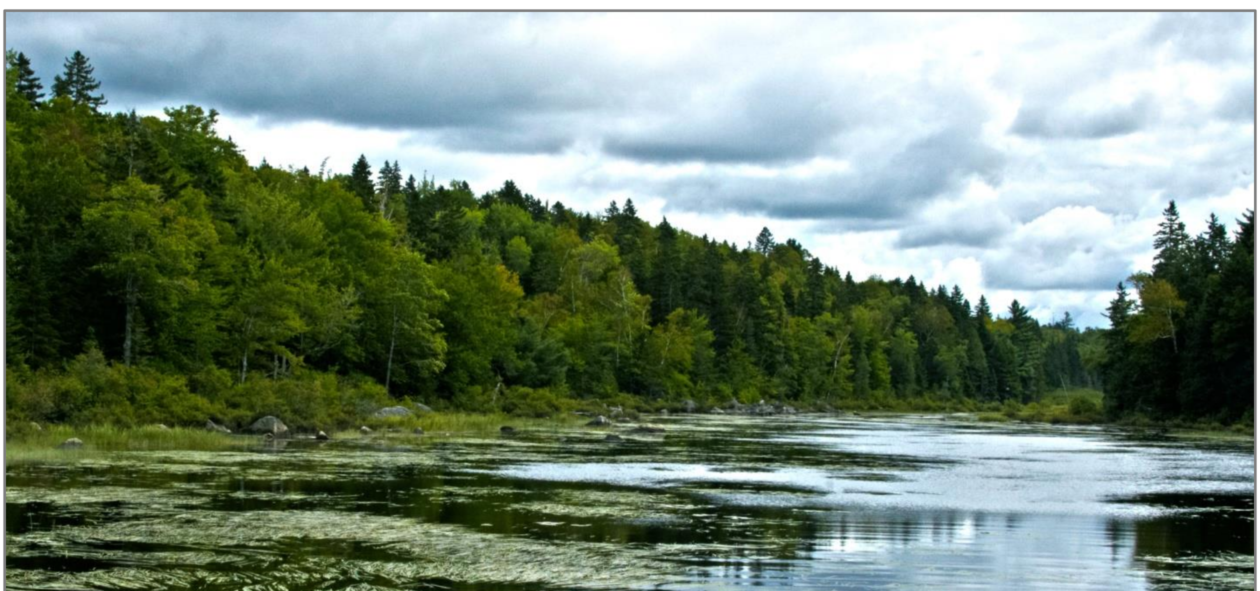
Utah Division of Wildlife Resources

Utah State University

Voisine Brothers

Wagner Forest Management

Washington County Council of Governments



Tomah Stream, Brookton, Maine (photo Pamela Wells)

Partnerships and Initiatives

Center for Advanced Forestry Systems

Robert Wagner and **Aaron Weiskittel**

Objectives

The goal of this project is to participate in a National Science Foundation (NSF) Industry/ University Cooperative Research Centers Program (I/UCRC). Specific objectives are to: (1) receive leveraged funding for research projects that are of interest to regional forest products industry members; (2) provide opportunities for graduate students and young scientists to receive training and interaction with the forest products industry; and (3) link with a national network of scientists to create collaborative, applied research projects that address critical needs for the forest products industry.

Approach

This past year represented the fourth year of participation in CAFS, is a multi-university center that works to solve forestry problems using multi-faceted approaches and questions at multiple scales, including molecular, cellular, individual-tree, stand, and ecosystem levels. Collaboration among scientists with expertise in biological sciences (biotechnology, genomics, ecology, physiology, and soils) and management (silviculture, bioinformatics, modeling, remote sensing, and spatial analysis) is at the core of CAFS research. Led by North Carolina State University, CAFS is a consortium of university/industry forest research cooperatives at University of Maine, Oregon State University, Purdue University, Virginia Polytechnic Institute, University of Georgia, University of Washington, University of Idaho, and University of Florida.

This year CAFS funding two research projects: (1) Extension of the Acadian Variant of the Forest Vegetation Simulator (FVS) to intensively managed stands and (2) Examining the influence of precommercial and commercial thinning in balsam fir and red spruce stands across Maine. CAFS funding supported one graduate student this year (Patrick Clune, MS). Patrick is nearing completion of a 10-year analysis of growth responses from the CFRU Commercial Thinning Research Network.

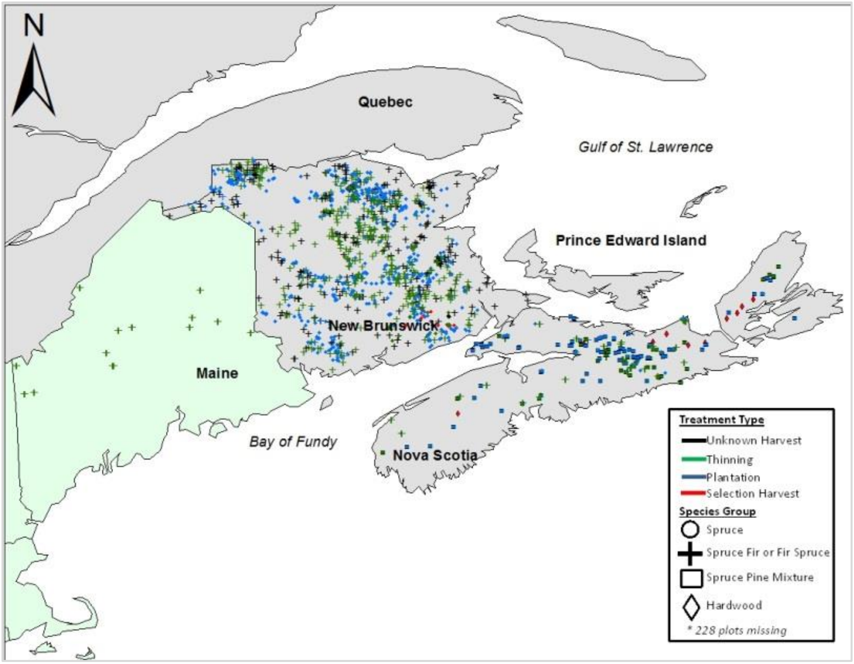


Figure 2. Map of permanent plot locations in the region that have received various forest management activities and be used to improve predictions of the Acadian Variant of the Forest Vegetation Simulator.

Results

For the Extending the FVS project, a standardized relational database of regional intensively managed permanent growth and yield plots has been compiled. Data from a total of 4311 plots has been acquired with the majority of the data being from plantations and thinned natural stands in New Brunswick (Figure 2). This year the data will be used to evaluate the performance Acadian Variant of FVS in managed stands and develop necessary modifiers to correct behavior. In addition, an alpha version of the Open Stand Model currently being developed by Dr. Chris Hennigar of the University of New Brunswick was released in April.

For the Examining the influence of thinning project, MS student Patrick Clune successfully defended his thesis and is currently working on revisions. Preliminary findings indicate that (1) spruce-fir stands that are merchantable and have never received a precommercial thinning (PCT), a low thinning improves stand structure, increases total and merchantable volume periodic annual increment (PAI), and increases financial returns (NPV) over not thinning; that crown thinning increases stand value, but results in less wind firm stand structures; and that dominant thinning severely degrades stand structure, substantially increases wind losses, and decreases subsequent stand growth; (2) spruce-fir stands that are merchantable and received an earlier PCT, all commercial thinning (CT) treatments substantially increased stand growth and improved stand structure relative to not thinning; volume growth was increased substantially at 33 and 50% CT intensities; and that 33% early CT increased cumulative stand value and NPV, while 50% delayed thinning decreased cumulative stand value and NPV; and (3) CT results in increased diameter growth and decreased crown recession on individual trees; only low thinning produces residual trees with favorable height diameter ratios (below 100) in No-PCT stands; all CT treatments maintain favorable height diameter ratios below 100 in PCT stands; and balsam fir and red spruce respond similarly to CT.

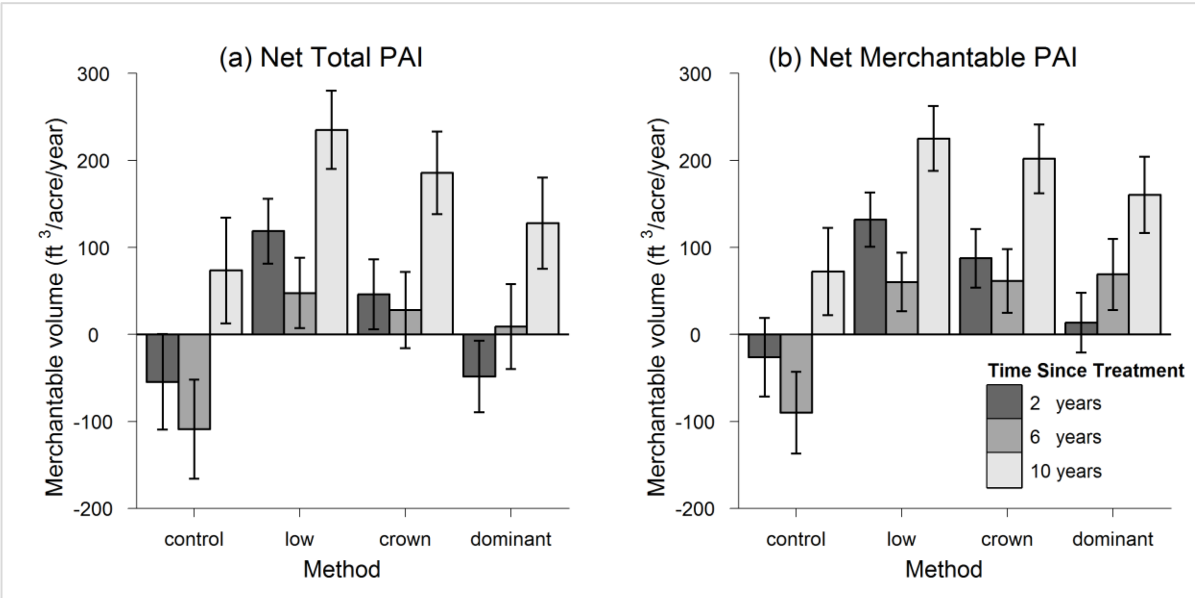


Figure 3. Net total (a) and merchantable (b) periodic annual increment (PAI) for different commercial thinning methods and time since treatment for spruce-fir stands with no prior precommercial thinning.

Impacts

Both CAFS projects have a clear benefit to the regional forest product industry as they address key questions regarding forest management. In particular, this research has allowed companies to better quantify and evaluate the financial viability of alternative forest management regimes, particularly PCT and CT. This is critical for harvesting scheduling, financial assessment, and efficient silvicultural decisions.

Funding

CAFS provides $70,000 per year to the University of Maine and CFRU members to advance growth and yield models for natural forest stands in the Northeast.

Forests for Maine's Future

Spencer Meyer

Forests for Maine's Future (FMF) is a partnership between four organizations: Maine Tree Foundation, Small Woodland Owners Association of Maine (SWOAM), Maine Forest Service (MFS), and CRSF. FMF believes that Maine's 17 million-acre forest resource is a vital part of Maine's economy and the social fabric of yesterday, today, and tomorrow. FMF's mission is *to promote sustainable forestry and educate people about the benefits and wonders of the forest that covers some 90 percent of our state*.

Under leadership by Sherry Huber (MTF), Spencer Meyer (CRSF), Tom Doak (SWOAM), and Kevin Doran (MFS), FMF builds awareness of Maine's forest resources through public outreach. FMF produces monthly feature articles, dubbed *Fresh From the Woods*, and delivers weekly newsletters with interesting news briefs about the woods in Maine and beyond. FMF strives to find unique stories that appeal to a broad audience and convey the special way-of-life the Maine Woods affords us. During this past year, our feature articles covered diverse topics including the Maine Land Trust Network, conservation easements, liquid fuels from the woods, and a new forest stewardship training program. More than 4,500 readers subscribe to our articles and newsletters.

Yellow Warbler (photo Pamela Wells)

With support from the Maine Outdoor Heritage Fund FMF received last year, we have redefined our approach to telling the world about Maine's forests. First we partnered with the Nature Conservancy, the Maine Forest Products Council, Maine Coast Heritage Trust, and the Forest Society of Maine to begin an effort to coordinate statewide outreach efforts focused on the woods. Second, we began working with Kingfisher Conservation and Recreation, LLC to develop a new communications plan. Our new approach, slated to begin Fall 2013, is to fully develop our social media presence on Facebook Twitter, and elsewhere. Finally, we will continue to publish our monthly feature articles that have been so popular. We expect our revamped program to send our message to a broader audience.

Sustainability Solutions Initiative

Spencer Meyer, Rob Lilieholm, and Jessica Leahy

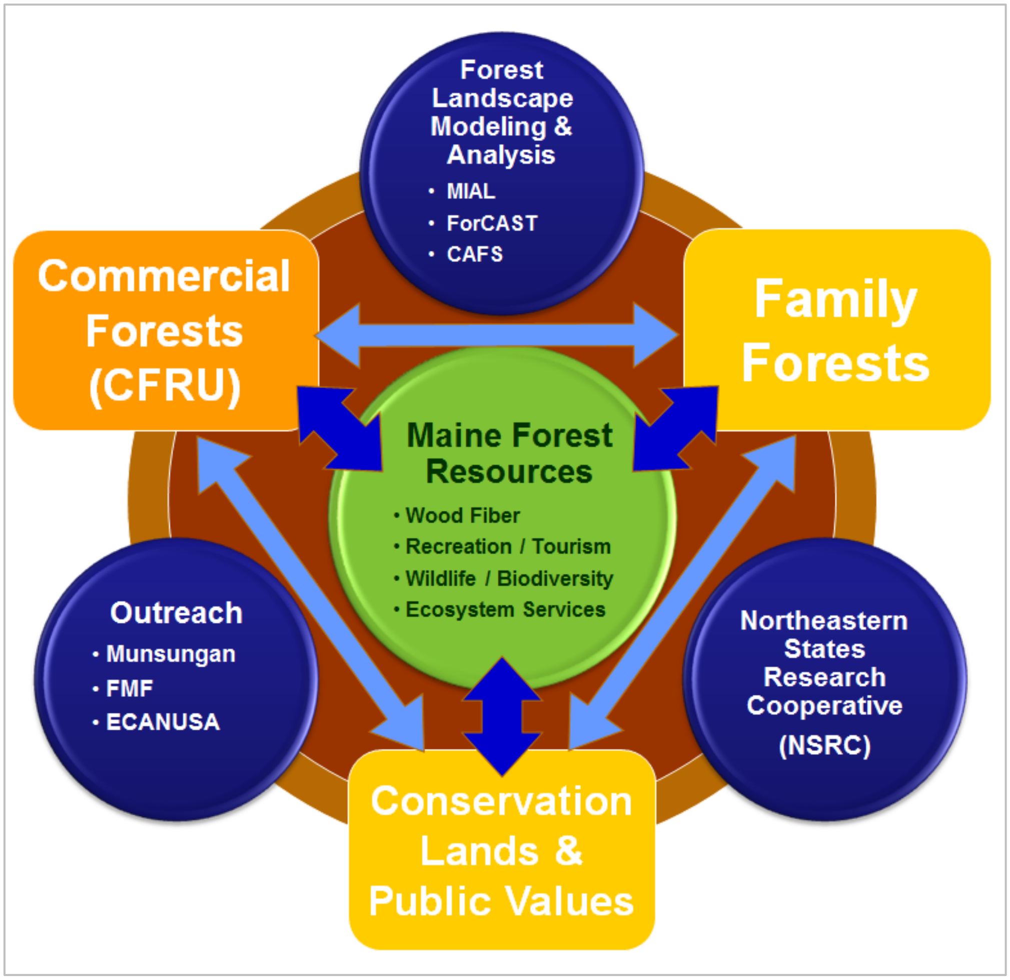
Through its *Family Forests Program* and *Conservation Lands Program*, CRSF maintains an active partnership with the Sustainability Solutions Initiative (SSI) at UMaine. SSI, housed in the *Senator George J. Mitchell Center*, is a National Science Foundation EPSCoR-funded program aimed at cutting across scientific disciplines to tackle challenging sustainability science problems.

Producing knowledge and linking it to actions that meet human needs while preserving the planet's life-support systems is emerging as one of the most fundamental and difficult challenges for science in the 21st century. Maine's Sustainability Solutions Initiative seeks to transform our collective capacity for addressing these challenges in ways that directly benefit Maine and other regions.

In 2013, several projects in the Family Forests Program and Conservation Lands Program were jointly funded by SSI. See the complete project descriptions later in this report.

Members of the SSI Forest Pest Outreach Evaluation team show their MeSSI pride.

CRSF Research Units



Family Forests Program

The Family Forests Program serves the estimated 120,000 private, individual forest landowners who own 5.7 million acres of forest land in Maine. These landowners, who own between 1-1,000 acres each, have largely been underserved in research and outreach that would enhance their forest stewardship. Therefore, the mission of the Family Forests Program is conduct to conduct applied scientific research and outreach that contributes to the sustainable management of Maine's family forests for desired products, services, and conditions in partnership with Maine's family forest stakeholders. These stakeholders range from the Small WoodlandOwner Association of Maine (SWOAM), USDA Family Forest Research Center, UMaine Cooperative Extension, American Tree Farm System (ATFS), Maine Forest Service (MFS), Natural Resources Conservation Service (NRCS), USDA State and Private Forestry, American Consulting Foresters (ACF) and other consulting foresters, Professional Logging Contractors of Maine and forest management firms offering services to family forest owners (e.g., Prentiss and Carlisle, Landvest, etc.).

The Family Forests Program has pursued four general lines of research and outreach over the last year: 1) Defining and identifying private landowner development intentions and their related stewardship values, 2) Developing an exploratory profileof low-income landowners in Maine, 3) Applying risk theory and other social science theories to predict woody biomass supply from family forest lands, and 4) Surveying the knowledge, attitudes, and behaviors of landowners toward invasive forest pests such as the emerald ash borer and Asian long-horned beetle.

American Woodcock (photo Pamela Wells)

Accomplishments include $318,665 in research and outreach funding from a variety of sources including the Northeastern States Research Cooperative, National Science Foundation (SSI/EPSCoR), McIntyre-Stennis, and the Small Woodland Owner Association of Maine. Additionally, eight publications and five presentations led to widespread sharing of research results for maximum impact.

Listening Beyond the Choir:

Finding the Voice of Low Income Landowners in Maine

Britt Townsend, **Jessica Leahy**, **Dave Kittredge**, **Robert Seymour**, and **Alan Kimball**

Lady Slipper (photo Pamela Wells)

Objectives

The overall goal of this project is to better understand low income landowners within the state of Maine so that they may be better served by future research and outreach efforts. The objectives are to:

1. Develop a literature review to assess and analyze existing information on low income landowners nationwide.
2. Use qualitative interviews to identify stewardship values, challenges, and opportunities of low income forest landowners in Maine.
3. Evaluate whether traditional research methods and outreach strategies are effective in reaching low income landowners.

Background

One often hears anecdotes of the "Land Rich, Cash Poor" - stories of landowners harvesting timber too soon to pay for medical bills or to replace a broken vehicle, or rumors of landowners selling because they could no longer afford their property taxes on their fixed incomes. Yet, there has been little scientific research performed on low income landowners in Maine (Flora and Flora, 2008). This study seeks to change this and offer potential solutions for how we might study, engage, and assist low income landowners with their forest stewardship. Traditional research methods, which include landowner surveys, may not be effective for studying low income landowners for reasons such as low literacy levels, rural transportation issues, time constraints, as well as a lack of internet service. As a result, our understanding of the stewardship values, challenges and opportunities faced by this unique demographic may be incomplete or in the least skewed. This study takes a qualitative, analytical approach employing semi-structured, in-person interviews to shed light on issues faced by these individuals. Researchers and professionals throughout Maine will gain new insight into the needs, preferences, and challenges of low income landowners.

Methods

This research project consisted of 20 semi-structured interviews with low income landowners throughout the state of Maine. Interviews were conducted during the summer of 2012 and typically lasted between 45 and 60 minutes. For this study, low income landowners included only those with a self-reported annual household income less than 200% above federal poverty income guidelines and who owned more than 10 acres of forestland. As human test subjects were involved, proposed research methods were approved by the University of Maine's Institutional Review Board (IRB) for the protection of human subjects before implementation. The interview process was semi-structured to allow respondents freedom in their answers. The interviews were conducted in an open-ended, conversational manner to allow interviewees to feel comfortable with the process and with the interviewer. A bidirectional, personal interviewing technique was employed to make respondents more apt to allow insight into oftentimes-sensitive areas, such as income figures.

Numerous methods for identifying and recruiting of potential participants were employed to engage this difficult to reach demographic. Initially, property tax records obtained from the University of Maine

White admiral butterfly (photo Pamela Wells

Center for Research on Sustainable Forests (CRSF) were used in conjunction with publically available, online telephone listings in an attempt to reach out to potential interviewees. The relative lack of success of this method of recruitment led to the development of alternative recruiting methods after the project was underway. Network sampling and community gatekeepers as well as mailbox flyers and online advertisements were also used as methods of identification and recruitment of potential participants. Those interviewed were compensated $75 for their time and all interviews were completed in-person at a location and time convenient to the interviewee. All interviews were recorded and transcribed verbatim. Interview transcripts were analyzed employing an iterative process that focused on identifying relevant themes, patters, and relationships concerning low income landowners.

Results

The analysis uncovered eight major recurring themes that embody the sentiments shared by many low income landowner study participants regarding the management of their lands and their stewardship ethic as a whole.

1. A Strong Connection With the Land -- Overall, low income landowners possess their land for diverse reasons, ranging from aesthetics to income, from creating a family legacy to creating a wildlife sanctuary. Nearly all of those interviewed possessed a strong

connection with their land. The majority of landowners interviewed owned their land for a purpose—and rarely was that purpose solely financial. Many landowners interviewed purchased their land to, as one interviewee put it, own "*a piece of Maine*."

2. Property Tax Concerns -- Property tax burdens weighed heavily on the minds of nearly all of those interviewed. All but one low income landowner said that paying their property taxes was a challenge and many feared losing their land. Without the tree growth tax incentive programs, many landowners acknowledged that they would have been unable to own land at all. Others held out transferring their properties into tree growth, fearing a loss of autonomy.

3. A Desire for Autonomy in the Management of One's Land -- A recurring theme that appeared in many of the interview transcripts was a desire for autonomy in the management of one's land. A high percentage of those interviewed desired little government or outside intervention in the management of their lands; as one interviewer put it, *"basically, I don't want other people telling me what to do!"*

4. Strong Community Ties -- As with many residents of Maine, most of the landowners interviewed resided in or owned land in small, rural communities. Many told stories of communities rallying together to support a common cause. One landowner succinctly and poignantly stated the overarching theme perfectly when they said, "*If I need anything, I know I can depend on people in [my] community*."

5. A Desire for Wilderness and Conservation -- Most of those interviewed expressed a strong desire for keeping their land minimally managed. Some even desired nearly a pure preservation approach, leaving their land as "*nature intended*" or "*wilderness*."

6. Active Trial-and-Error Learning of Management of Practices -- Nearly all of those interviewed were very active, in one way or another, in the management of their lands. Many desired to learn more about how to better manage their land themselves, but lacked the time or money to do so.

7. Temporal and Financial Constraints as Limiting Factors to Desired Management Practices -- Though nearly all of those interviewed had a strong connection with an interest in managing their land, many had not taken steps towards gaining additional knowledge in this area due to time and financial constraints. Many of the landowners interviewed considered themselves "*self-taught*" with regards to management expertise, and all wanted to learn more.

8. A Preference for "Walk-and-Talk" and Other Interactive Outreach Methods -- Overwhelmingly, landowners interviewed exhibited a strong preference for bidirectional outreach methods that allowed them actively take part in the learning process, asking specific questions that they had about their own lands. Many landowners had not actively sought out aid with forest management because of time and financial

constraints. Others simply did not know that services existed to help them learn proper forest management techniques.

Impacts

This study identifies a unique set of needs, preferences, and challenges of low income forest land owners in Maine as well as offers potential solutions for how we might more effectively study, engage and assist low income landowners with their forest stewardship in the future. Very little information exists on this silent demographic within the forest community, and even less on those residing within the state of Maine. While these individuals exist, the forestry community continues to direct much of its efforts towards the “model landowner.” The stereotypical or “model landowner” is an older, white mail with a college education and a keen interest in learning about and managing his small woodlot (McCaskill et al., 2008). By contrast existing literature characterizes the low income landowner as having a definite interest in generating income from their land, a poor education, and would consider selling their land “when the price is right” (Kluender and Walkingstick, 2000; Blatner et al., 1991; Munn et al., 2007). However these stereotypes may be an artifact of research methods and outreach strategies currently employed by researchers, educators, and other professionals.

Overwhelmingly, the results of this study show that the interests and goals of low income landowners differ little from those of the model landowner. There exists a great deal of similarity between the findings of this study and previous research on both the model owner and other low income and low-income NIPF landowners, with a few notable caveats. Low income landowners possess many similarities to the model owner but find themselves constrained by a lack of time and money. Just like the model owner, these individuals have a strong, personal connection to their land and a deep interest in managing it. Their management objectives, overall, mirror those of the model landowner. The significant difference that exists between these two groups is resources, both temporal and financial. Though similar, a segmented approach to outreach is still necessary in order to effectively reach this subgroup of individuals. Although they desire many of the same things for their land, individuals within this group are oftentimes simply unable to afford the services they want and many do not know where to look for the information. More free and low-cost outreach programs targeted towards this unique audience must be created in order to effectively engage these individuals. Additionally, for this group, the services provided by extension personnel may be of particular importance, especially in Maine, where there exists few public service foresters. Perhaps with the added insight provided by this exploratory study, future research may be more effectively tailored to this unique demographic group and better provide for their specific set of needs.

Understanding Landowner Stewardship Responsibilities

Michael Quartuch, **John Daigle**, **Jessica Leahy, Kathleen Bell**

Introduction

Forest ecosystems produce fiber, clean air and water, sequester carbon from the atmosphere, maintain biodiversity, wildlife habitat, soil and nutrient stability, and offer a wide array of recreational and aesthetic opportunities (Beckley 1999; Stein, McRoberts, Alig, Nelson, Theobald, et al. 2005). Throughout the world, however, human activities and land use decisions are resulting in the loss of wildlife, biodiversity, and natural resources including fisheries and forests (Chapin, Power, Steward, Pickett, Reynolds, et al. 2011; Ostrom 2009). Furthermore, many of the ecosystem services and amenity values discussed above are disrupted when forest lands are split into smaller lots or converted for residential development (Stein, Alig, White, Comas, Carr, et al. 2007; White, Alig, and Stein 2010). Residential development, for example, permanently alters the landscape and can have unintended consequences on natural resources, wildlife, forest management, and overall quality of life. Sustainable forest management is one approach to assuring that social, ecological, and economic attributes are conserved over time. Therefore, it is vital that forest managers and forest landowners become aware of this stewardship approach to optimize benefits of maintaining large intact forests for themselves as well as society at large.

Common yellow-throat warbler (photo Pamela Wells

Private forest landowners: U.S. and Maine

Over 264 million acres of forest land in the United States rests upon the shoulders of over 10.4 million individuals and families (Butler 2008). These landowners supply approximately 50 percent of the nation's timber harvest (Powell, Faulkner, Darr, Zhu, and MacCleery 1993) and provide various recreational, aesthetic, and economic opportunities. Research suggests however, that as the number of forest landowners increases, both the average parcel size and the number of written forest management plans decrease (Butler 2008; Butler and Ma 2011; Mehmood and Zhang 2001; Sampson and DeCoster 1997; Sampson and DeCoster 2000). Furthermore, researchers have found that increasing population densities and urban expansion often result in declining rates of commercial timber harvesting and active forest management

(Kline, Azuma, and Alig 2004; Munn, Barlow, Evans, and Cleaves 2002; Wear, Liu, Foreman, and Shefield 1999).

Many Northern states are experiencing such trends and Maine is no exception. Nearly one-third of the total forest land (about 5.7 million acres) in the state of Maine is owned by over 200,000 family forest landowners (Maine Department of Conservation 2009; McWilliams, Butler, Caldwell, Griffith, and Hoppus 2005). These individuals and families are predominantly located in the central and southern regions of the state (Maine Department of Conservation 2010). Increasing parcelization and the conversion of forests for development threaten the long term sustainability of these forests to provide both amenity values and economic opportunities. Thus, in order to understand why landowners behave in ways that change (or do not change) forested landscapes will require a deeper exploration of landowner stewardship ethics and a comprehensive assessment of landowner attitudes and social norms.

Previous Research

Over the past ten years the number of research efforts seeking to segment or classify landowners based on reasons for owning land, previous behavior (e.g. timber harvesting), and other socio-demographic characteristics (e.g. income) has increased (Finley and Kittredge 2006; Kendra and Hull 2005; Kluender and Walkingstick 2000; Ross-Davis and Broussard 2007). Applying segmentation analysis to landowner populations has helped resource professionals better understand who these individuals are and how best to serve this portion of the population. However, less attention has been given to understanding the role that individual attitudes and social norms may play for example, when influencing specific behaviors (e.g. development). Further, the concept of land stewardship provides a unique measure with which to gauge why landowners may or may not be acting in ways that effectively change forested landscapes (Quartuch and Beckley 2012). Thus, in an effort to identify the role that attitudes, norms, and stewardship responsibilities play in influencing landowner behavior we apply the theory of planned behavior and hypothesize that landowner stewardship responsibility will increase the predictive capacity of the model.

Objectives

1. To explain the variance in landowner development intentions through attitudes, norms, and perceived behavioral controls
2. To examine whether the inclusion of landowner stewardship responsibilities increase the predictive capacity of the theory of planned behavior model

Conceptual framework

Theory of planned behavior

The theory of planned behavior (TPB) suggests that human social behavior is guided by a variety of salient beliefs. These beliefs provide the foundation for one's attitudes, perceived social norms, and perceptions of behavioral control which in turn, influence an individual's behavioral intentions. In this framework, behavioral intentions represent the direct antecedent to performing (or not performing) a given behavior (Fishbein and Ajzen 2010) (Figure 4). Ultimately, "the more favorable the attitude and perceived norm, and the greater the perceived behavioral control, the stronger should be the persons' intention to perform the behavior in question" (Fishbein and Ajzen 2010, p. 21).

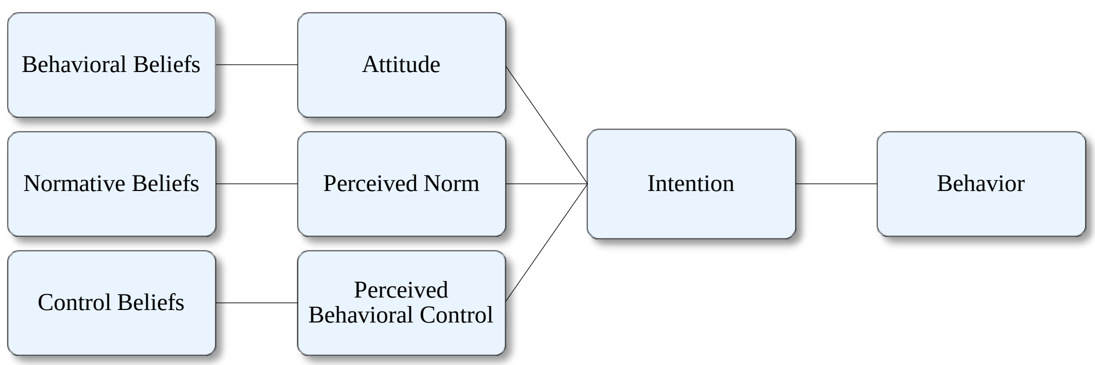


Figure 4. Theory of planned behavior.

Within the TPB framework attitudes, norms, and controls successfully account for anywhere between 30 to 90 percent of variance in behavioral intentions (Armitage and Conner 2001; Fishbein and Ajzen 2010). However, the individual contribution of each construct often varies depending on the population and behavior under investigation. For example, perceived social norms are often one of the least significant predictors across various health-related behaviors (Godin and Kok 1996). This finding has led researchers to consider expanding the normative component to include personal or moral norms (Godin and Kok 1996; Kaiser 2006; Papagiannakis and Lioukas 2012). In an effort to better understand landowner development intentions we conceptualize stewardship responsibilities as a personal or moral decision separate from the perceived social norm construct (Figure 5).

Stewardship

The term stewardship refers to an ethical or moral obligation to care for something on behalf of someone (or something) else and shares similarities with sustainable forest management and resource conservation. The primary difference between stewardship and other types of management is an explicit focus on responsibly managing land on behalf of: society, future generations, plants/animals and self/familial interests (Worrell and Appleby 2000). By understanding landowner stewardship responsibilities resource professionals and policy makers will be able to better engage with landowners and target specific landowner needs based on a more comprehensive, value-orientation, rather than management objectives and reasons for owning land, alone.

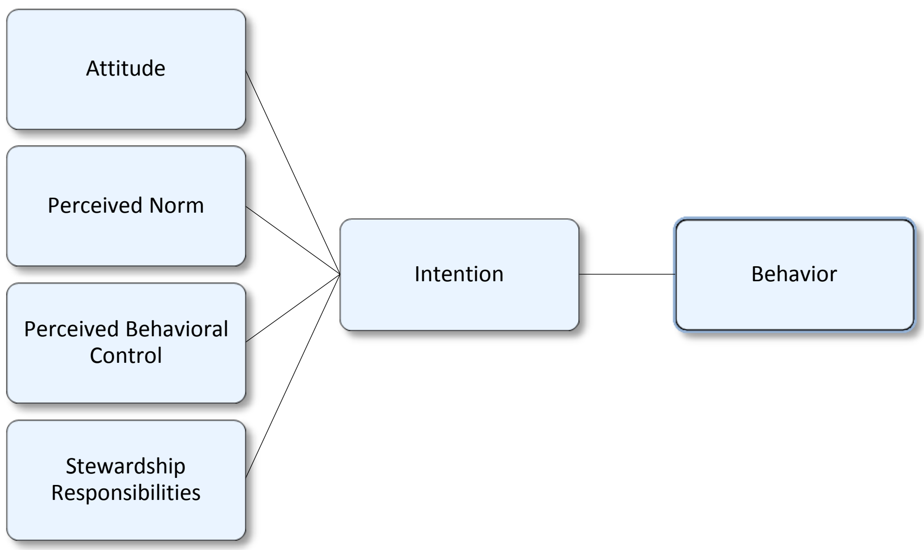


Figure 5. Conceptual model depicting potential relationship between stewardship and intention.

Approach

Using the 2009 and 2010 CRSF landowner property tax database, our sample included records from all towns within Kennebec County, with the exception of Randolph and Oakland. We created a master list of all non-commercial property owners with 10 - 1,000 acres of total land and from these data, 900 landowners were randomly selected and included in our sample. A mailed questionnaire titled, Kennebec County Woodland Owner Survey, was created and comprised of 9 sections with a total of 38 questions. The nine primary sections in the survey assessed various interests ranging from forestry assistance programs and green certification to TPB variables and stewardship responsibility.

The majority of questions were either binary (yes/no), or contained statements where participants would indicate their level of agreement/disagreement, preference, or likelihood, along a 5-point Likert scale. Survey administration followed a modified Dillman's Tailored Design method (Dillman, Smyth, and Christian 2009) where respondents received four different contacts over a five week period. A total of 456 deliverable surveys were returned while 44 were "returned to sender" or were unable to be delivered. The overall response rate was 53 percent. Non-response bias was examined by comparing early versus late respondents based on demographic variables and landowner characteristic (e.g. age, employment situation, gender, amount of woodland owned) (Armstrong and Overton 1977). No significant differences were found. As this research is on-going, descriptive statistics will be provided below followed by preliminary results regarding TPB and stewardship responsibility findings.

Results: Descriptive statistics

Socio-demographic and landowner attributes

The majority (66.5 percent) of woodland owners in Kennebec County own between 1-50 acres of forest land, have owned their parcel(s) for approximately 24 years (average), live on their woodland and are between the ages of 51-75 years old (68.3 percent). Over 80 percent of survey respondents are male (19.4 percent female) and approximately 86 percent are either "retired" or are "working full time." When making decisions about how to use or manage woodland, almost 73 percent of respondents are making decisions with input from another (joint) owner while 23.7 percent of respondents are the sole owners of their woodland.

Land use and management

Findings from the National Woodland Owner Survey suggest that family forest landowners own land to enjoy beauty or scenery, because it is part of the farm or homestead, for privacy, to pass on to heirs, and to protect nature and biologic diversity (Butler and Leatherberry 2004). Similarly, the top three reasons why Kennebec County woodland owners own forest land are: "Part of my primary home" (62.6 percent), "To enjoy beauty or scenery" (59.8 percent), and "For privacy" (61.1 percent). Only 15.7 percent of participants own land "For production of saw logs, pulpwood, biomass, or other timber products." Over half of participants have conducted a commercial timber harvest on their woodland and 74.2 percent of these individuals were "somewhat" to "very satisfied" with the outcome. The majority of Kennebec County woodland owners have never used a forestry assistance program and most (73.9 percent) do not currently have a written forest management plan. However, about 36 percent of respondents would consider using a forestry assistance program and almost 67 percent would consider using a management plan or are unsure. When asked what would encourage woodland owners to acquire a written management plan, 60.1 percent identified getting "a property tax reduction," 41.7 percent suggested finding "ways to improve wildlife," and 34.8 percent indicated getting "professional advice about how to improve my land."

Results: Inferential statistics

Predicting development intentions from attitudes, norms, controls, and stewardship variables

A five step process was used to analyze data and will serve as the foundation for the remainder of this section. First, following Hrubes, Ajzen, and Daigle (2001), the internal consistency of TPB item pairs was tested by calculating Pearson correlations for each variable. Correlations were of significant magnitude and were subsequently averaged and used in the second phase of analysis.

Second, landowner attitudes, norms, and controls were used as independent (predictor) variables in a multiple linear regression. Development intentions served as the dependent variable. Overall, each of the three TPB constructs were statistically significant and accounted for 42 percent of the variance in development intentions ($R = .650$, $p < 0.001$). At an individual level, attitudes were the largest single contributor in the model (standardized Beta = .406) while perceived norms were the least significant contributor (standardized Beta = .151).

Although statistically significant, these findings do not indicate whether landowners are more (or less) likely to develop their forest land due to underlying attitudes, norms, and controls. Thus, the third step involved grouping respondents by their development intentions and comparing groups to their responses to attitude, normative, and control statements. To accomplish this, an n-way ANOVA was conducted and Tukey HSD post-hoc was administered. Statistically significant differences were identified among the three groups and across the three TPB variables (Table 2). The first group in (Table 2) is comprised of landowners who are unlikely or highly unlikely to develop their land. These individuals held unfavorable attitudes toward developing their property, believe the people closest to them would disapprove of developing, and held lower perceptions of control about developing their land (i.e. it would be difficult to do). The third group represents individuals who are likely or highly likely to develop their forest. These landowners held favorable attitudes toward developing their land and feel like it would be easy to do. These findings provide empirical support for using the theory of planned behavior within this population (i.e. landowners) and across this behavior (i.e. development).

Table 2. Empirical support for using the TPB with this population across development intentions.

	Group 1 (N=232) Unlikely – highly unlikely to develop	Group 2 (N=61) Neutral on developing land	Group 3 (N=29) Likely – highly likely to develop
Attitudes	Unfavorable attitudes	Neutral attitudes	Favorable attitudes
Norms	People closest to them would disapprove	Neutral feelings as to whether people closest to them approve or disapprove	People closest to them were neutral or would somewhat approve
Controls	Low ability to develop; difficult to do	Neutral perceptions of control	High ability to develop; fairly easy to do

Fourth, a principal components analysis (PCA) was performed on nine stewardship responsibility items. The PCA helped to reduce these data and identify the underlying structure across stewardship variables (Hair, Anderson, Tatham, and Black 1995). The nine stewardship items included a range of entities (e.g. future generations, plants, self, etc.) and participants were asked whether they agreed/disagreed that they have a responsibility to consider each entity when using their land. Three statistically significant factors were derived and labeled: Biotic community, Social responsibility, and Myself and my family (Table 3). Table 3 presents the individual factor loadings for each variable as well as the internal consistency (Cronbach's alpha) for the first two principal components. The third factor, Myself and my family, is comprised of only two variables, therefore a Pearson correlation is provided. Factor scores were retained for each of the three principal components and were used in subsequent analysis.

In order to examine whether landowner stewardship responsibilities would increase the predictive capacity of the TPB model (i.e. objective 2), a second multiple linear regression was performed. All three TPB variables were included in the regression model followed by the three factor scores derived from the PCA. Landowner development intentions once again served as the dependent variable. Findings from this regression analysis suggest that adding stewardship responsibility factor scores to the TPB model do not result in a statistically significant increase in the prediction of landowner development intentions.

Table 3. Three factor stewardship solution with corresponding factor loadings.

Stewardship responsibility to...	Factor 1 Biotic community	Factor 2 Social responsibility	Factor 3 Myself and my family	Internal consistency of items
Plants	.912			
Animals	.883			
The land	.832			
Future generations	.593			$\alpha = .866$
Neighbors		.849		
Community		.914		
Society		.779		$\alpha = .854$
Myself			.644	
My family			.818	r = .162, p< 0.001

One potential reason why stewardship responsibilities did not increase the predictive capacity of the model could be due to a mediation effect. For example, having a responsibility to the Biotic community might be captured by one's attitude toward developing forest land. Thus, the question then became, do landowner stewardship responsibilities significantly influence (or help predict) landowner attitudes toward development or perceptions of normative pressure and behavioral control? Three separate multiple linear regressions were conducted in order to answer these questions. In each regression model the three stewardship responsibility factor scores were included as independent variables and the attitude, norm, and control constructs were added as dependent variables. Statistically significant relationships were identified between stewardship responsibilities and attitudes as well as perceived behavioral controls. No statistically significant relationships were discovered between stewardship responsibility and perceived norms.

Results from the first regression analysis revealed that having a heightened sense of responsibility to the Biotic community resulted in unfavorable attitudes toward developing forest land. Additionally, having a higher responsibility to Myself and my family resulted in favorable attitudes toward developing land. Interestingly, having a greater responsibility to the Biotic community resulted in landowners feeling less control over developing their property. Lastly, a greater Social responsibility resulted in higher perceptions of control (i.e. it would be easy to do). Specific implications of these findings will be discussed in detail below.

Implications: Theoretical

At a theoretical level this study provides empirical support for using the TPB framework to predict behavioral intentions. Specifically, findings indicate that landowner attitudes, norms, and controls predict up to 42 percent in landowner development intentions with attitudes comprising the majority of explained variance. The perceived social norm was statistically significant but was the weakest single contributor overall. This finding corroborates previous research suggesting a need to re-conceptualize the theory's normative component.

The inclusion of landowner stewardship ethics as a separate, normative construct is not fully supported. However, landowner stewardship responsibilities do play a role, albeit indirectly, in influencing behavioral intentions through attitudes and perceived behavioral controls. Interestingly, having a responsibility to the Biotic community, Myself and my family, and an overall Social responsibility did not influence perceived social norms. Thus, in context of this behavior (developing forest land) and among this population of landowners, few individuals perceive a social pressure to steward their property. On the contrary, having a greater Social responsibility resulted in higher perceptions of control which in turn, influences landowners to be more likely to develop their property. Two implications can be drawn from this finding. First, landowner's Social responsibility may not play as important of a role when considering how to use or manage one's land especially in comparison to other responsibilities (e.g. Biotic community or Myself or my family). Second, there may be additional, external factors (e.g. private property rights) which need to be considered when discussing personal or social norms.

Impacts: Applied

The findings presented in this report offer practical solutions for natural resource organizations, agencies, and policy makers. Based on the descriptive data agencies or organizations interested in encouraging active forest management may want to target landowners that are undecided or "not sure" about whether they would obtain a written forest management plan, participate in forestry assistance programs, or conduct future commercial harvests. With regard to written forest management plans for example, respondents indicated that being able to improve wildlife habitat might influence them to obtain a plan.

The notion of wildlife habitat improvement was further supported when asked about stewardship. Participants identified a heightened sense of responsibility to the biotic community or, plants, animals, and the land itself. These individuals were also less likely to develop their property. Thus, resource professionals interested in engaging with woodland owners can use this information to target outreach and education efforts that entail an increased emphasis on promoting wildlife/wildlife habitat. Additional outreach efforts may be required to address those landowners that constitute the second group within Table 2. These individuals hold neither favorable nor unfavorable attitudes toward developing their land and are essentially "on the fence" as to whether they should (or should not) engage in this behavior. By tapping into what resonates with these individuals and families such as caring for the land, may help them better meet their land management goals and in turn, conserve working forest land. Based on our results, policy makers may want to consider adjusting current incentive programs to include additional opportunities for landowners to further reduce property taxes. If this is not possible it may be prudent for policy makers to re-frame the message of incentive programs in a way that emphasizes the ability of these programs to enhance wildlife habitat.

Funding

- Maine Forest Service
- National Science Foundation, Maine EPSCoR award EPS-0904155 (SSI)

Work Cited

Armitage, C. J., and Conner, M. (2001). Efficacy of the theory of planned behavior: A meta-analytic review. *British Journal of Social Psychological Society*, 40, 471-499.

Armstrong, J. S. and T. S. Overton. (1977). Estimating nonresponse bias in mail surveys. *Journal of Marketing Research*, 14(3), 396-402.

Butler, B. (2008). Family forest owners of the United States, 2006. Gen. Tech. Rep. NRS-27. Newton Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

Beckley, T. M. (1999). Forest community sustainability: Introduction to the theme. *The Forestry Chronicle* 75(5), 745-746.

Butler, B. J. and Leatherberry, E. C. (2004). Americas family forest owners. *Journal of Forestry* 102(7), 4-14.

Butler, B., J. and Ma, Z. (2011). Family forest owner trends in the Northern United States. *Northern Journal of Applied Forestry*, 28(1), 13-18.

Chapin, F. S., Power, M. E., Steward, T. A., Pickett, A. F., Reynolds, J. A., Jackson, R. B., et al. (2011). Earth stewardship: Science for action to sustain the human-earth system. *Ecosphere*, 2(8), 1-20. Doi:10.1890/ES11-00166.1

Dillman, D. A., Smyth, J. D., and Christian, L. M. (2009). *Internet, mail, and mixed-mode surveys: The Tailored Design Method*. John Wiley and Sons Inc., Hoboken, New Jersey.

Finley, A. O. and Kittredge, D. B. (2006). Thoreau, Muir, and Jane Doe: Different types of private forest owners need different kinds of forest management. *Northern Journal of Applied Forestry*, 23(1), 27-34.

Fishbein, M. and Ajzen, I. (2010). Predicting and changing behavior: The reasoned action approach. New York, New York: Taylor and Francis Group.

Godin, G., and Kok, G. (1996). The theory of planned behavior: A review of its applications to health-related behaviors. American Journal of Health Promotion, Inc., 11(2), 87-98.

Hair, J. F., Rolph E. A., Tatham, R. L., and Black, W. C. M*ultivariate Data Analysis with Readings*. Fourth ed. Englewood Cliffs, NJ: Prentice Hall, 1995.

Hrubes, D., Ajzen, I., and Daigle, J. (2001). Predicting hunting intentions and behavior: An application of the theory of planned behavior. *Leisure Sciences*, 23(3), 165-178.

Karippinen, H. (2005). Forest owners' choice of reforestation method: An application of the theory of planned behavior. *Forest Policy and Economics*, 7(3), 393-409.

Kaiser, F. G. (2006). A moral extension of the theory of planned behavior: Norms and anticipated feelings of regret in conservationism. *Personality and Individual Differences*, 41(1), 71-81.

Kendra, A., and Hull, R. B. (2005). Motivations and behaviors of new forest owners in Virginia. *Forest Science*, 51, 142-154.

Kline, J. D., Azuma, D., and Alig, R. J. (2004). Population growth, urban expansion, and private forestry in Western Oregon. *Forest Science*, 50(1), 33-43.

Kluender, R. A. and Walkingstick, T. L. (2000). Rethinking How Nonindustrial Landowners View Their Lands. *Southern Journal of Applied Forestry*, 24(3), 150-158.

Maine Department of Conservation, Bureau of Forestry, Forest Policy and Management Division. (2009). *Report on Maine forest service district forester program*. Augusta, ME. Retrieved from http://www.maine.gov/doc/mfs/pubs/rtf/2007_field_forester_rpt.rtf-2008-12-02

Maine Forest Service, Department of Conservation. (2010). *Maine state forest assessment and strategies*. Maine Forest Service, Department of Conservation, Augusta, ME. Retrieved from http://www.maine.gov/doc/mfs/mfs/state_assessment/index.html

Metzler, J., Morin, R., Sader, S., Stewart, L., Steinman, J., Westfall, J., Williams, D., Whitman, A., and Woodall, C. (2005). The forests of Maine: 2003. Resource Bulletin NE-164. Newton Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station.

Mehmood, S. R., and Zhang, D. (2001). Forest parcelization in the United States: A study of contributing factors. *Journal of Forestry*, 99(4), 30-35.

Munn, I. A., Barlow, S. A., Evans, D. L., and Cleaves, D. (2002). Urbanizations's impact on timber harvesting in the south central United States. *Journal of Environmental Management*, 64, 65-76.

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, 325(24), 419-422.

Papagiannakis, G., and Lioukas, S. (2012). Values, attitudes and perceptions of managers as predictors of corporate environmental responsiveness. Journal of Environmental Management, 100, 41-51.

Powell, D. S., Faulkner, J. L., Darr, D. R., Zhu, Z., and MacCleery, D. W. (1993). Forest resources of the United States, 1992. USDA Forest Service Rocky Mountain Forest and Range Experiment Station General Technical Report RM-234.

Quartuch, M. R., and Beckley, T. M. (2012). Landowner perceptions of their moral and ethical stewardship responsibilities in New Brunswick, Canada and Maine, USA. *Small-scale Forestry*.

Ross-Davis, A. and Broussard, S. (2007). A typology of family forest owners in north central Indiana. Northern Journal of Applied Forestry, 24(4), 282-289.

Sampson, R. N. and DeCoster, L. (1997). Public programs for private forestry: A reader on programs and options. Washington, DC: American Forests.

Sampson, R. N. and DeCoster, L. (2000). Forest fragmentation: Implications for sustainable private forests. Journal of Forestry, 14, 29-46.

Stein S. M., Alig, R. J., White, E. M., Comas, S. J., Carr, M., Eley, M., Elverum, K., O'Donnell, M., Theobald, M., Cordell, D. K., Haber, J., Beauvais, T. (2007). National forests on the edge: Development pressures on America's national forests and grasslands. Gen. Tech. Rep. PNWGTR-728. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 26 pp.

Stein S. M., McRoberts, R. E., Alig, R. J., Nelson, M. D., Theobald, D. M., Eley, M., Dechter, M., Carr, M. (2005). Forests on the edge: Housing development on America's private forests. Gen. Tech. Rep. PNW-GTR-636. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 16 pp.

Wear , D. N., Liu, R., Foreman, J. M., and Shefield, R. M. (1999). The effects of population growth on timber management and inventories in Virginia. *Forest Ecology Management* 118, 107-115.

White, E. M., Alig, R. J., and Stein, S. M. (2010). Socioeconomic changes and forestland development: Commonalities and distinctions between the Eastern and Western United States. *Journal of Forestry*, 108(7), 329-337.

Worrell, R. and Appleby, M. C. (2000). Stewardship of natural resources: Definition, ethical and practical aspects. *Journal of Agricultural and Environmental Ethics*, 12(3), 263-277.

What Works? Evaluating Forest Pest Outreach Efforts

Crista L. Straub, Jessica E. Leahy, John J. Daigle, and Sandra M. De Urioste-Stone

Yellow-bellied sapsucker (photo Pamela Wells)

Objectives

Determine the most effective methods of outreach that will influence the behaviors of landowners, campers, and other stakeholders of Maine, New Hampshire, and Vermont to protect their forest resources from invasive tree-killing pests and associated pathways.

Approach

Project activities include the following: 1) Northern New England Landowner Survey, 2) Volunteer and Outreach Impact Evaluation, and 3) Firewood Movement Behavior Survey. For the Northern New England Landowner Survey, a representative, randomly-selected sample of landowners in higher risk areas of Maine (ME), New Hampshire (NH), and Vermont (VT) will be surveyed. Three thousand total homeowners (1,000 from each state) will be randomly selected and mailed a questionnaire. The Volunteer and Outreach Impact Evaluation comprises 2 focus groups in ME, NH, and VT with volunteers to gain feedback on the outreach program. In addition to providing a technical report summarizing findings and suggesting recommendations, we will develop a survey questionnaire that can be administered to outreach volunteers before and after future training, and a brief evaluation form that will be developed for volunteers to use while providing outreach. The final deliverable – Firewood Movement Behavior Survey – includes on-site surveying at campgrounds in ME, NH, and VT. A goal of 18 sampling days with 30 responses per day will yield 540 camp user participants.

Impacts

Our research will employ a number of social science techniques that will help us determine the most effective outreach methods to increase public awareness of invasive forest pests and firewood movement. The techniques and model developed for this project can be adapted for evaluation of other educational campaigns. In addition, our research will advance approaches used to investigate landowner and camper perceptions, knowledge, attitudes, and behaviors toward invasive forest pests and firewood movement. There are limited studies that have investigated these essential topics, and even less that have implemented a combined theoretical framework.

Funding

- Crista L. Straub, Jessica E. Leahy, John J. Daigle, and Sandra M. De Urioste-Stone. 2013. "What Works? Evaluating Forest Pest Outreach Efforts." Submitted to Maine Department of Agriculture, Conservation, and Forestry. $74,951. Funded.

Pre-commercial thinning, Wells Forest (photo Pamela Wells)

Small Woodland Owner Timber Harvesting Behavior:

The Missing Link Between Stated Attitudes and Observed Behaviors

Jessica Leahy, Aaron Weiskittel, Emily Silver, Caroline Noblet, and David Kittredge

Objectives

This review synthesizes existing literature from North America and Europe, identifies trends in study design and methods, and suggests future research opportunities. Synthesis objectives were to: 1) identify how past research defined and analyzed harvesting behavior; 2) describe the evolution of these methods; 3) determine the extent to which previous research linked land owners' stated attitudes to observed harvesting behavior; and, 4) suggest opportunities for future research. This project is ongoing.

Approach

Over 100 articles from 1970–2013 that were published in peer-reviewed journals, government reports, and dissertations were analyzed, which were used for determining trends, broad themes, and opportunities for future research. Articles were gathered using snowball sampling from major scientific search engines, and supplemented with Internet research on state and federal forest management programs.

Expected Results

Preliminary results indicated that researchers believe a mix of qualitative (i.e. focus groups and interviews) and quantitative (e.g. surveys) methods are best, but few studies utilize both. Additionally, the impact of landowner risk perception, in relation to a harvesting decision, has not been extensively studied. Many studies purportedly studied behavior, but actually measured stated preference or attitudes. Few studies validated stated preferences or attitudes by measuring observable harvesting behaviors.

Impacts

Understanding small woodland owner timber harvesting behavior is essential to measuring and predicting worldwide timber supply. Given the decline of harvesting on public and industrial land, as well as increasing parcelization, small woodland owners could be an increasingly important timber source. We present a new methodology for explicitly linking stated attitudes with observed timber harvesting behaviors by validating models with harvest data or by developing longitudinal prospective and retrospective cohort studies. A better understanding of small woodland owner timber harvesting behavior will inform timber supply prediction and support forest management outreach efforts.

Funding

- University of Maine’s Sustainability Solutions Initiative
- Northern States Research Cooperative (to J.L., A.W., and E.S)

Landowner Thinning (photo Pamela Wells)

Resolving a Critical Question in Predicting Woody Biomass Supply to the Northern Forest Industry:

Estimating Risk Perception and Willingness to Harvest from Small Woodland Owners

Jessica Leahy, Aaron Weiskittel, and Emily Silver

Objectives

We aim to determine the willingness of small woodland owners to harvest timber for biomass in three Northern Forest regions. Specific objectives are to: 1) Create a comprehensive literature review on woodland owner attitudes towards multiple aspects of woody biomass, 2) Identify current policies and regulatory mechanisms that relate to landowner perception of risk towards biomass harvesting, 3) Examine risk perception of small woodland owners specifically related to harvesting timber for biomass production, and 4) Provide recommendations to state and local policy makers, town planners, regional conservation groups, and the forest products industry that suggest ways to provide outreach to small woodland owners and build collaborations between landowners, loggers, and biomass facilities. This project is ongoing.

Small feller-buncher, Wells Forest (photo Pamela Wells

Expected Approach

We will conduct a literature and policy review, to explore existing survey data and interview transcripts for relevance to our study. Following this exploration of secondary data, we will conduct semi-structured interviews and/or focus groups with up to 20 landowners owning between 10-1,000 acres in Maine, Vermont, and New Hampshire. We will recruit interview and/or group participants using the networks within landowner associations, state forestry agencies, Cooperative Extension, and others. We will also use existing land trust, NGO's, and regional conservation partnership knowledge to identify landowners in these regions. Interviews will be conducted in person, whenever feasible. Based on the themes and patterns illuminated in these interviews or groups, we will develop a mail survey to be administered to 1000 randomly chosen small woodland owners distributed in our three regions proportional to population density of these woodland owners.

Expected Results

With the lack of biomass facilities and the already depressed timber market in the Northern forest, we hypothesize that small woodland owners perceive a high risk to biomass harvesting.

Impacts

Our understanding of this risk perception will help inform policy makers and the forest products industry about the feasibility of biomass as a renewable energy option. In addition to the applied significance, the use of risk theory (the study of decision-making under probabilistic uncertainty) with small woodland owners would make a new contribution to forest social science.

Funding

- Sustainability Solutions Initiative
- NSF Sustainable Energies Pathways grant

Skidder - Wells Forest (photo Pamela Wells)

Conservation Lands and Public Values Program

Maine has led the nation in the development and application of innovative land conservation tools, especially when it comes to private lands and the protection of working forests. Maine currently has nearly 3.5 million acres of land protected from development. These lands provide a host of public and private benefits, ranging from parks and working forests, to wildlife habitat and biodiversity protection. Together, these protected areas provide both recreation and ecosystem services for current and future generations of Mainers, and have been protected through the combined efforts of federal (e.g., Forest Legacy), state (e.g., Land for Maine's Future) and a host of municipal and non-governmental groups, including nearly 100 land trusts.

The landscape mosaic of developed and undeveloped lands in the northeastern U.S. has progressively changed at various spatial scales in response to land use and development pressures, socioeconomic influences, expansion of transportation networks, and non-uniform state and local regulatory frameworks. As ongoing processes of urbanization have transformed open spaces and agricultural property into developed land uses, there has been a remarkable counter-balancing expansion of public and private land conservation activities aimed at protecting biodiversity, scenic values, working forest lands, ecosystem services, recreational opportunities, and special natural areas in the remaining undeveloped land base.

Because land use changes and conservation efforts in the region have occurred incrementally at multiple scales and in a variety of jurisdictions, it is challenging to assess the aggregate impacts of these cumulative land use decisions on environmental quality, resilience, and long-term sustainability in the overall landscape.

CRSF's research program on Conservation Lands and Public Values seeks to assist decision-makers and planners as they look to the future and increasingly think strategically about balancing land conservation, working lands protection, and land development activities. Program activities are designed to: (1) help develop a clear understanding of the current status, extent, and landscape patterns of conserved lands across the region; (2) determine what kinds of values and conditions are represented in conserved parcels; (3) account for the dominant processes and criteria driving conservation activities across the different states of the Northeast; and (4) develop tools that help a wide range of stakeholders understand land use change and explore alternative future development paths.

Understanding how these lands are ultimately protected, managed and valued by current and future generations will significantly affect the sustainability of Maine's communities and related forest-based industries, including forest processors and the recreation and tourism sector.

Alternative Futures Modeling for the Lower Penobscot and Lower Androscoggin River Watersheds in Maine

Rob Lilieholm, Christopher Cronan, Dave Owen, Spencer Meyer, Michelle Johnson, and Thomas Parr

Objectives

The U.S. Forest Service projects that by 2030, both the Lower Penobscot and Lower Androscoggin River watersheds in Maine (Figure 6) will experience significant increases in urbanization and losses of private forestland. The Lower Androscoggin is among the 15 watersheds nationwide at greatest risk of development. The University of Maine's Sustainability Solutions Initiative (SSI), in cooperation with CRSF, has identified these watersheds as prime study areas to develop a new, stakeholder-driven land use planning tool using alternative futures analyses. The overall goal of the project is to spatially assess the suitability of four critical land uses across these two watersheds: (1) economic development; (2) forestry; (3) conservation; and (4) agriculture. In assessing these suitabilities, compatibilities and potential conflicts can then be identified under a range of stakeholder-defined futures scenarios. This research goes beyond typical conservation planning by evaluating an array of possible futures across multiple land uses. These results will then be available on-line through the Maine Community Mapper, which will help communities and conservation organizations better prioritize their protection efforts while allowing policy makers and planners to consider alternate policy strategies.

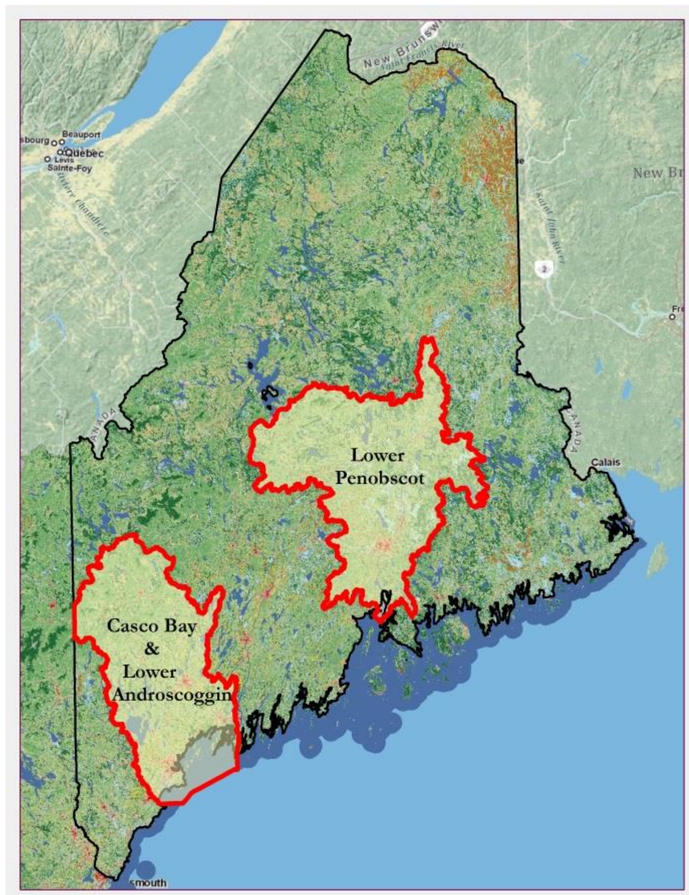


Figure 6. These two watersheds encompass nearly 4.5 million acres that contain the most densely populated cities in Maine.

Approach

Since 2010, the research team has led focus groups on each of our four land uses with more than 70 stakeholders (Figure 7). Stakeholders included policy makers, conservationists, farmers, foresters, business leaders, and scientists.

Through these focus groups, we identified key factors affecting the suitability of each of our four land uses, and then co-developed models for land use suitability within each watershed.

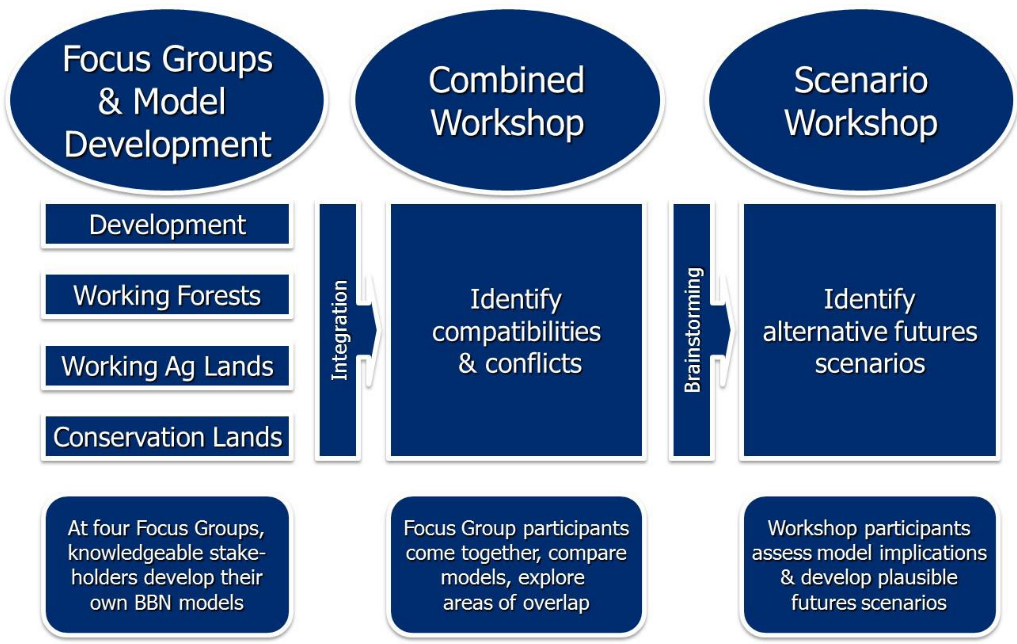


Figure 7. Conceptual model describing the stakeholder engagement process used for focus groups representing each land use.

Using a technique called Bayesian belief networks (BBN), expert opinion gleaned through the focus groups was combined with existing geospatial information from a variety of state agencies, conservation organizations, and other sources. Using the relative ratings for each factor as determined by our stakeholders and influence diagrams, we then produced land use suitability maps for the two study areas. For example, in the conservation influence diagram (Figure 8), the various factors of suitability for ecosystem protection come together to identify ecosystem services, biodiversity, and recreation as three pillars of conservation. Each land use has its own influence diagram, which result in each of the suitability maps below (Figure 9).

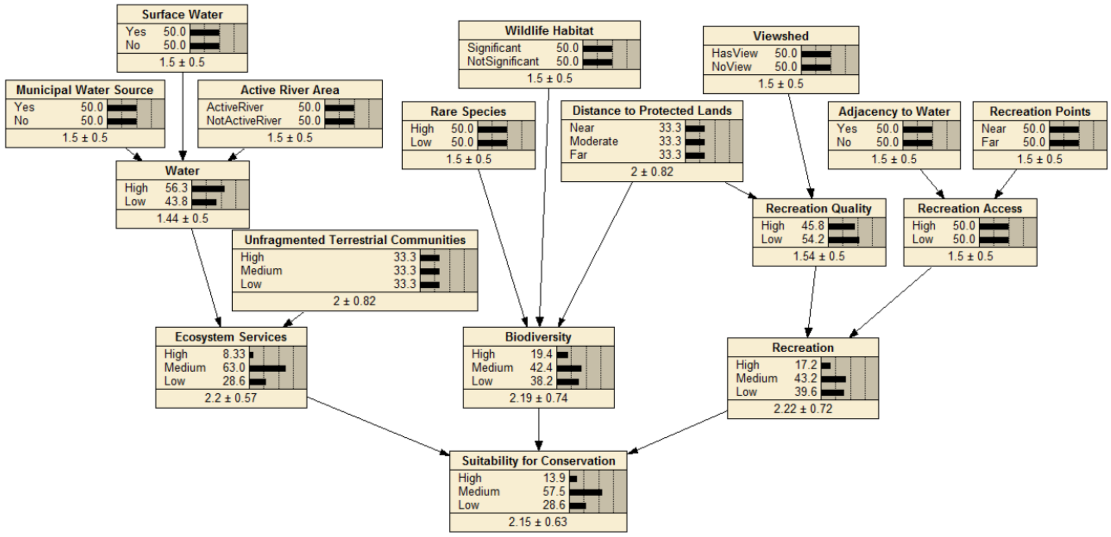


Figure 8. Bayesian belief network influence diagram showing relationship between factors contributing to overall suitability for ecosystem conservation.

Next, a combined workshop allowed focus group stakeholders from each of the four land uses to come together to envision conflicts and opportunities for competing and complementary land uses (
Figure 7). We are currently developing a set of futures scenarios through ideas generated with our stakeholder partners. These futures scenarios range from varying levels of development, to changes in agricultural practices due to global energy markets, to "what-ifs" about how conservation and forestry can co-manage landscapes for a variety of products and ecosystem services.

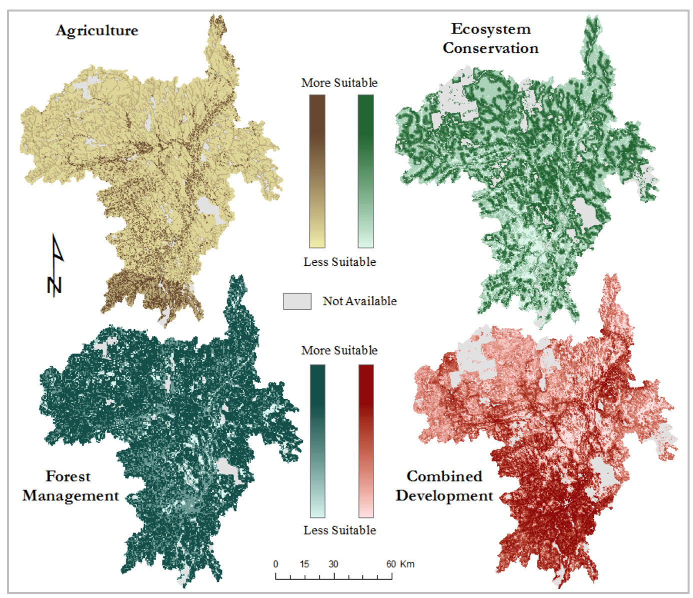


Figure 9. Land use suitabilities for four land uses in the Lower Penobscot River Watershed.

.

Results

Based on our four land use suitability models, we have begun to explore the potential for future conflict and compatibilities in the 2.5-million-acre Lower Penobscot River Watershed. For example, (Figure 10) shows areas highly suitable for conservation (green), as well as the overlap between areas suited for both conservation and development (red). These areas of overlap between two non-compatible land uses show areas of potential future conflict, and are of concern to both conservation and development stakeholders.

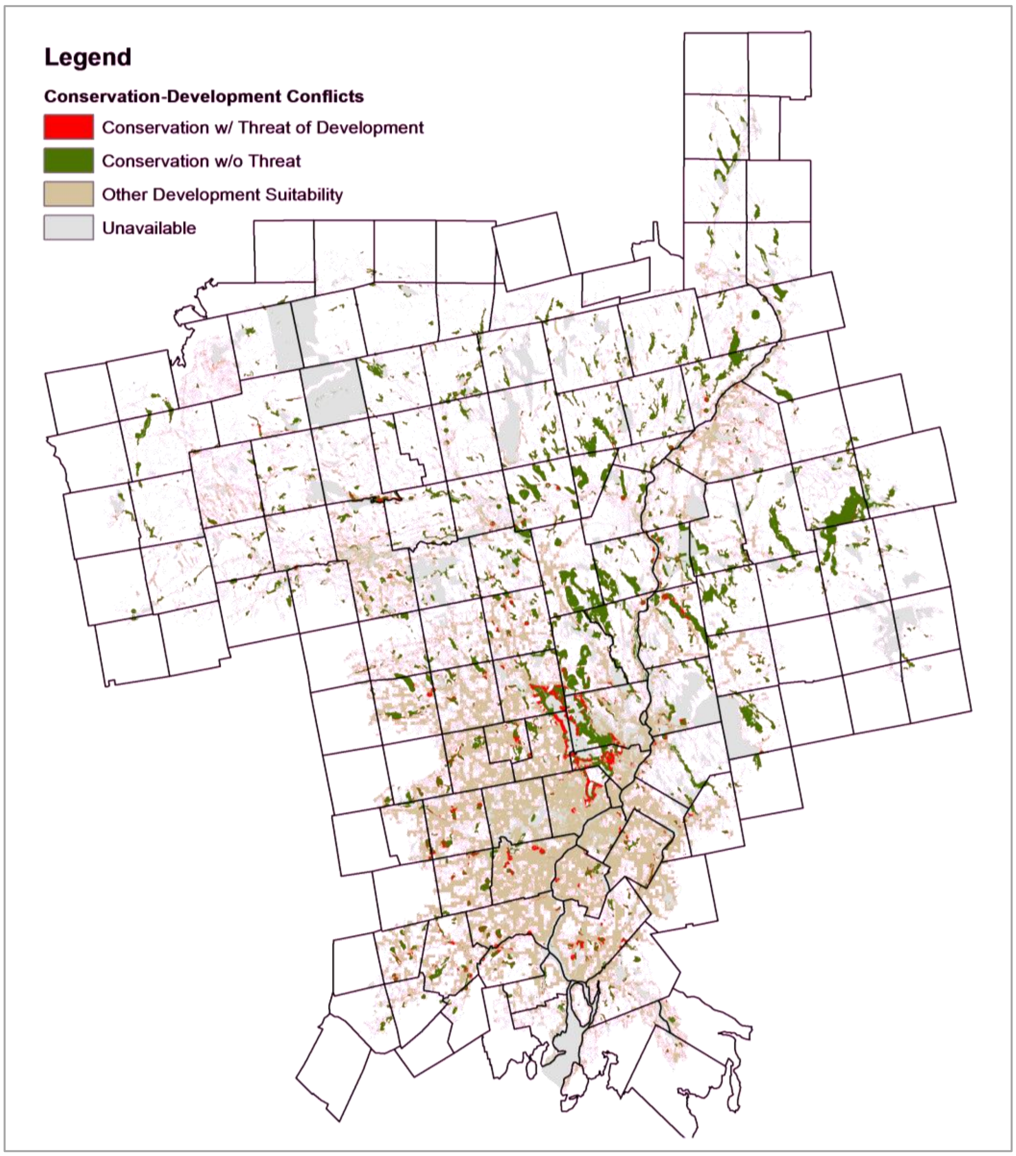
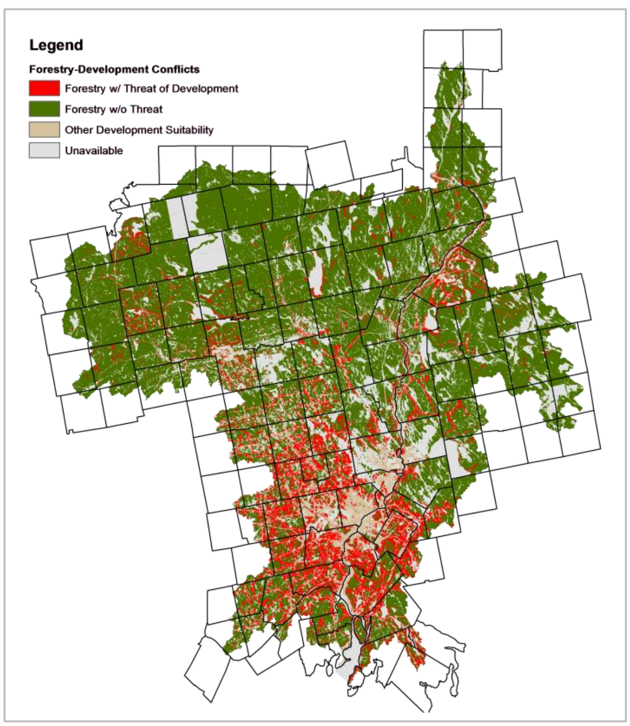


Figure 10. This map identifies areas that are highly suitable for conservation, development, and both, which indicates potential conflicts.

In Figure 11 (left), green areas depict lands highly suitable for forestry, while red areas show lands highly suitable for both forestry and development. Once again, these red areas depict areas of concern for both forestry and development interests. In Figure 11 (right), we show lands highly suitable for both forestry and conservation in dark green (note that the balance of highly suitable conservation lands are shown in light green). Here, depending upon conservation objectives, these dark green areas represent locations where these two interests may share a common goal in protecting land from development. Indeed, working forest management and ecosystem conservation are often complementary. Conservation non-profit organizations in Maine hold more than 1.8 million acres of conservation easements, most of which are on working forestlands in the state. Organizations such as the Nature Conservancy and the Appalachian Mountain Club have partnered with large forest products companies to protect some of the most significant ecosystems across the state, while maintaining a steady stream of forest products, ecosystem services, and jobs for Maine citizens. By identifying areas of overlap between such complementary uses, our research is intended to foster future partnerships. Moreover, based on our focus group interactions, development interests are also eager to identify these areas, largely because areas of competing interests oftentimes pose additional and/or unforeseen challenges in realizing development proposals.



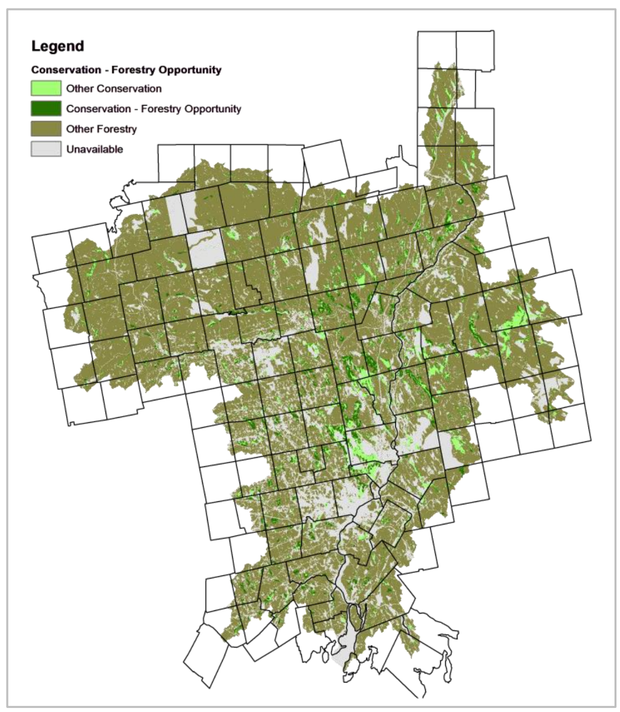


Figure 11. These maps identify areas of potential conflict for forestry and development (left), and areas of opportunity that are both suitable for forestry and conservation objectives (right).

Finally, Figure 12 depicts lands highly suitable for development that are not highly suitable for the other three land uses (i.e., forestry, conservation, and agriculture). These lands, located near existing population centers and infrastructure, represent opportunities for future development that do not compromise areas important for competing and oftentimes incompatible land uses. Once again, based on our focus groups, identifying these lands is of interest to a wide range of stakeholders. For example, in many Maine communities, residential and second-home development is incrementally threatening intact forestlands and important wildlife habitats. Such dispersed development can strain municipal budgets as new development demands new services while existing infrastructure such as roads, schools, sewers and water systems are underutilized. Identifying lands suitable for development that leverages existing community assets, as shown in Figure 11, has the potential to mitigate losses to traditional land uses while keeping tax rates low.

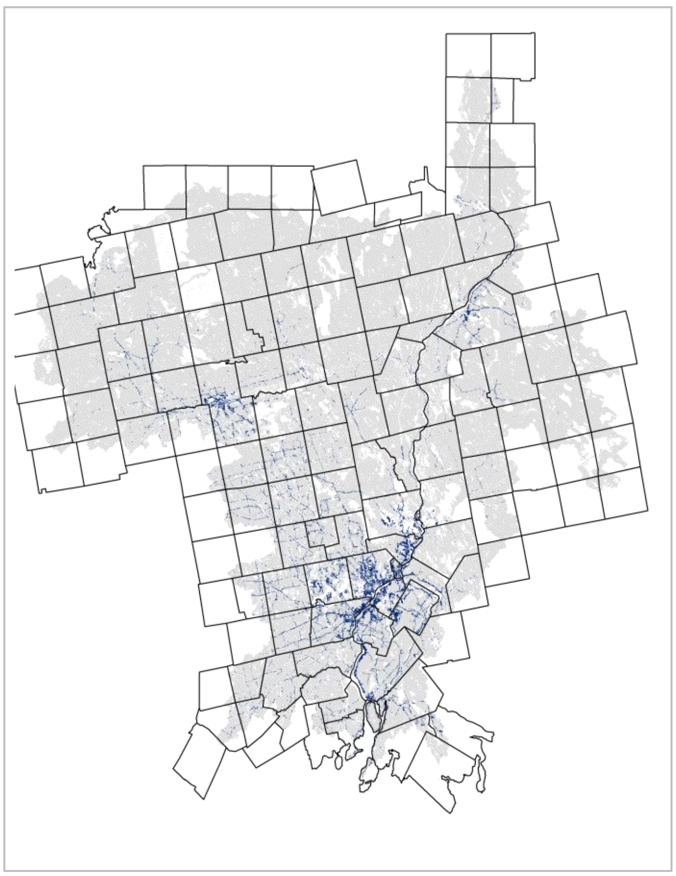


Figure 12. Blue areas indicate land suitable for development, but which are not highly suitable for other land uses.

Impacts

A core feature of sustainable development policies is the protection of sustainable economic activity, vibrant communities, and environmental quality. In Maine, protecting these assets is an important economic development strategy. Understanding landscape change drivers through interdisciplinary research therefore is critical to sustaining human and natural systems. Equally important is the process of engaging stakeholders in the research process, and understanding how scientific knowledge can be transformed into meaningful solutions.

Alternative futures modeling is an effective way to foster improved understanding of existing land use, and of the intricate and dynamic connections between human and natural systems. In Maine, the approach is particularly relevant given the close economic and social ties between the state's landscape and its people. Ensuring the health of these systems is not only important to quality-of-life, but also the sustained viability of the tourism and forest products sectors.

Our work engages stakeholders across a broad range of interests including conservation, government, business and real estate development. This breadth allows us to better understand the factors likely to drive future challenges and opportunities affecting Maine's landscape. Our stakeholder-derived models of land suitability provide the public with quantitative, spatially explicit depictions that not only inform key stakeholders of current land use and suitability, but also allow various interests to design and evaluate the effects of alternative assumptions regarding population growth and development pressures on current and future landscapes. Most importantly, our modeling is designed to facilitate the identification of locations where compatibilities and conflicts in projected land use are likely to exist across time in response to differing assumptions embodied in future land use scenarios.

Funding

- National Science Foundation, Maine EPSCoR award EPS-0904155 (SSI)
- Elmira B. Sewall Foundation
- Northern States Research Cooperative

Sunkhaze Stream, Sunkhaze Meadows, National Wildlife Refuge (photo Pamela Wells

Mobilizing Diverse Interests to Address Invasive Species Threats:

The Case of the Emerald Ash Borer in Maine

Brown-eyed Susan (photo Pamela Wells)

Darren Ranco, Rob Lilieholm, William Livingston, John Daigle, Theresa Secord, Jennifer Neptune, Molly Lizotte, Kara Lorian, and Paul Szwedo

Objectives

This project seeks to study and facilitate the ways that Wabanaki basket makers, tribes, state and federal foresters, various university researchers, landowners and others come together to prevent, detect, and respond to the emerald ash borer (EAB) – a potentially devastating invasive insect threat to ash trees in Maine. We hope to help these stakeholders work together to manage for potential impacts so that Maine and the Wabanaki people will not lose the brown ash (*Fraxinus nigra*), a valuable economic and cultural resource. We believe that collaborating knowledge and joining together for collective action with engaged stakeholders will lead to more effective and sustainable action in responding to EAB.

Approach

Addressing complex resource management challenges such as EAB requires structured dialogue between scientists, resource users, and interested publics informed about human-environment systems – a process called analytic deliberation. Analytic deliberation "improves the effective use of information; enhances conflict resolution, consensus and adaptive governance; and builds cooperation between local stakeholders and the state" (Robson and Kant 2009). Our strategies in bringing together resource users — especially those who are most potentially impacted by EAB — reflect our belief that analytic deliberation will lead to the best knowledge and governance solutions to manage the threat of EAB.

Through a series of stakeholder workshops, we have laid the groundwork for a research plan identifying four areas of collaborative research: (1) mapping ash resources; (2) developing policy guidance; (3) stakeholder engagement; and (4) seed collection. In tandem with determining these objectives, we are studying how a group of stakeholders develops and interacts over time, with a particular emphasis on how different power positions and forms of knowledge intersect to create barriers and opportunities for sustained collaboration. We are using qualitative research methods such as participant observation, focus groups, and individual interviews to track the barriers/opportunities for collaboration, recognize and integrate different forms of knowledge, and foster the creation of policy so that an invasive threat such as EAB can be prevented, detected, and addressed. We are particularly interested in how the group interacts in a context where power and knowledge are unevenly shared and how we, and the group, are able to create power-sharing.

We consider this collaborative research plan to be a living document that will be further defined with other structured interactions with key stakeholders over the coming years. To address the development of policy guidance, we have analyzed management information from state and federal agencies and other relevant parties in areas where EAB has already emerged. We are using this information to facilitate the development of a pre-invasion management and emergency response plan. To address the mapping of ash resources, we will integrate the expert knowledge of Wabanaki brown ash harvesters with existing scientific knowledge and spatial GIS data to identify locations in Maine that are more or less likely to be suitable habitat for brown ash. Expert knowledge will be linked with empirical data within a Bayesian Belief Network (BBN) that will be used to map areas having site characteristics that promote ash growth and regeneration, as well as areas that may contain stress factors. This work, along with site-specific ecological studies of ash growth and silvicultural characteristics, has recently been expanded through a $180,000 grant from the USDA Forest Service.

Preliminary Results

Thus far, we have gathered baseline data through participant observation to understand the different ways that stakeholders see themselves participating in the process for sustainable collective action around EAB as an invasive threat. Our facilitated workshops with key stakeholders have identified primary areas of research, and spearheaded a response planning process in Maine. The emerging stakeholder group includes a half-dozen tribal members engaged in basket ash harvesting and basketry, as well as representatives from the University of Maine's scientific community, the USDA Forest Service, the Maine Forest Service, representatives from Maine Indian tribal governments, the Bureau of Indian Affairs, the United States Forest Service, the Animal Plant Health Inspection Service (APHIS) of the USDA, and a number of environmental non-profits and indigenous basket-makers from Michigan, where the EAB has already devastated much of the ash resource.

Part of our process has included experiential learning opportunities for Native American youth from the Penobscot Nation-Indian Island school in how to identify and gather ash seed. Over the last several years, we developed the Maine EAB Trap Tree Network (TTN) in cooperation with the USDA Forest Service, Maine Forest Service, and the Small Woodlot Owners Association of Maine. TTN is engaging woodland owners from across the state to voluntarily create trap trees (girdled 4-to-6-

inch DBH ash trees) to serve as early detection monitors. As our work continues, we will continue to assist Maine and Wabanaki tribal governments in developing EAB response plans. Monitoring and seed collection efforts will continue as well, along with meetings and workshops to spur dialogue and collaboration between stakeholders. Finally, we have completed a white paper on EAB emergency response plans in areas already affected by EAB. This paper is serving to guide the State of Maine as it develops its own response plan.

Anticipated Impacts

The outcomes of this project include: (1) the creation of a guidance document to help the state and tribes develop cooperative emergency response plans for the arrival of EAB; (2) continued focus group interviews on stakeholder engagement questions; (3) BBN focus groups and field-based ecological research to help identify the location of ash resources in Maine; (4) continued stakeholder engagement in the development of research needs and questions; (5) a stakeholder meeting on research coordination with an emphasis on public education and outreach; and (6) the documentation, with key stakeholders, of best practices for invasive species policy. Through this approach, our intent is to demonstrate how diverse groups can work together to develop invasive species emergency response plans that address key forest health challenges while including a diverse array of stakeholders.

Funding

- National Science Foundation, Maine EPSCoR award EPS-0904155 (SSI)
- USDA Forest Service. 2011-2014. Improving Emerald Ash Borer Monitoring and Management Prioritization - 3 year CARP Funding (Livingston, Daigle, Lilieholm and Ranco). $182,000

Stakeholders gather at a focus group to identify opportunities for collaborations to mitigate invasive species threats

Protecting Natural Resources at the Community Scale:

Vernal Pools as a Model System to Study Urbanization, Climate Change, and Forest Management

Pickerel frog (photo Pamela Wells)

Aram Calhoun, Jessica Jansujwicz, Rob Lilieholm, Jessica Leahy, Kathleen Bell, Malcolm Hunter, Cynthia Loftin, Linda Silka, Laura Lindenfeld, Nuri Emanetaglo, Dawn Morgan, Brittany Cline, Luke Groff, and Vanessa Levesque

Objectives

Our overall goal is to better understand how amphibian movements in complex landscapes are affected by forest management and urbanization. Of particular concern are effects on dispersal and population dynamics of vernal pool-breeding amphibians, and how regulatory and incentive-based policies can be integrated across mixed-use, privately-owned landscapes. Specific objectives include: (1) studying the effects of different land-use and forest management practices on amphibian dispersal and migration, with the goal of understanding how these movement processes affect population dynamics and persistence; and (2) studying the behavior of municipalities and landowners to better identify opportunities for protecting and sustaining vernal pools on private lands.

Approach

Our team is comprised of biophysical researchers and social scientists, and is integrated with an ongoing Vernal Pool Mapping Program (VPMP) currently in its 6th year. Research on pool-breeding amphibians is driven by the needs of regulators and planners identified through stakeholder meetings. We use mail surveys and focus group data in five of the VPMP towns to inform our work, with three model towns chosen from our VPMP municipalities. We are combining findings from our work to develop conservation guidelines with our stakeholders.

Using vernal pool conservation in distinct landscapes as an entry point, we are working with and studying municipal and regional decision-makers. Our research addresses three specific aims: (1) identifying how lessons and challenges of vernal pool conservation can be applied to other resource management issues; (2) exploring the extent to which social and ecological feedbacks and thresholds influence municipal decisions; and (3) evaluating how boundary organizations influence municipal decision-making processes. We employ a mixed-methods/theoretical social science approach to achieve these aims. Using case studies of two to three “model towns” working to adopt innovative conservation planning techniques, we examine how towns approach single species/system conservation as compared to a mixed system approach. The three “model towns” are a subset of towns participating in the on-going VPMP initiative. Building on knowledge gained from this and other team research, we take stock of lessons learned about vernal pool conservation, compare and contrast decision-making around this and other issues, and focus on what local characteristics serve as indicators of actors that are likely to engage in innovative management. We employ regression analysis, GIS, network, and social science survey and focus group methods to examine the influence of demographic, socio-economic, and biophysical characteristics on decisions by municipalities to participate in relevant programs and/or adopt specific types of regulation. Of particular interest are how changes in social and ecological landscape attributes affect patterns in municipal participation and adoption. Lastly, we initiate research of interactions between boundary organizations and municipal actors, with a goal of exploring the science-policy-public interface, and the mediation of conflicting values and social goals at local and regional levels.

Results

We have used a new experimental approach to examine the relative effects of different types of urban vs. agriculture vs. forest habitats on permeability to dispersing juvenile wood frogs. This work has provided an enhanced understanding of the dynamics of the social-ecological systems associated with amphibian population persistence in landscapes influenced by the socio-economic factors that shape land-use (e.g., timber harvest, lawns, hayfields, and row crops). We are also examining multi-scale (both spatial and temporal) components of amphibian habitat needs in complex landscapes that contain many thresholds, such as aquatic/terrestrial edges. This approach is required due to amphibians’ biphasic life cycles (i.e., aquatic eggs and larvae, and terrestrial adult stages), as well as annual movements among different habitat types for breeding, foraging, and hibernating.

Our team is also dedicated to providing the biophysical and social science that informs vernal pool policy and, more broadly, town conservation planning on private lands. We have engaged in 75 stakeholder events with hundreds of people from dozens of organizations at federal, state, local, NGO, and private citizen levels. We have successfully engaged with model towns, including Topsham, Cumberland and Orono, where we work on solutions that incorporate human dimensions into local conservation planning. Our specific task is to foster practical town plans that address natural resource conservation on private lands while allowing for economic growth in development zones. Our social survey work with citizens has already led to modifications to our outreach strategies, and has also informed our biophysical research, expanding it beyond forestry to include amphibian responses to landscape changes associated with residential development and farming.

Our stakeholder group working on this project includes federal, state (three agencies), and local officials, as well as legal experts – all committed to revitalizing underused tools and helping to develop new solutions for linking conservation with opportunities for growth and development. Using participant observation, interviews, and focus groups, we investigated the use of VPMAP as a new model of engagement for more effectively linking scientific knowledge, stakeholder decision-making, and on-the-ground outcomes. We found that VPMAP mobilized support for collaborative community-based management, enhanced awareness and understanding of vernal pools and regulations at the local level, built stronger stakeholder relationships, and improved participatory local planning through a process of collaborative learning. However, we also found that communication with municipal officials and private landowners was a significant barrier for the effective functioning of VPMAP as a participatory model to engage a wider network of stakeholders in proactive planning. We suggest an expanded citizen science model that puts communication with municipal officials and private landowners on par with recruitment, training, and data collection by citizen scientists.

We are also examining the social "thresholds" and contributing factors that influence stakeholder acceptability of community-based vernal pool conservation planning in four southern Maine towns. For example, we are interested in the circumstances under which a private landowner will permit access to their property for a biological survey. We are also interested in determining what limits on development might be acceptable to landowners, and at what point landowners perceive vernal pool regulations as a "taking" of property rights. Using mixed-methods, we constructed a frame-based private landowner typology to identify landowner response patterns to vernal pool conservation in Maine. Interviews and focus groups identified a range of responses in two categories of frames, one describing positive views of vernal pools and the other negative views. A mail survey identified three groups of private landowners (Positive, Neutral, and Negative) with similar socio-demographic and property variables but different aesthetic preferences, economic concerns, and views on property rights and conservation. Our results suggest that frame-based typologies are useful for enhancing communications with different landowner groups and in identifying trusted information sources and communication preferences. Our approach represents a critical first-step toward understanding and integrating a range of landowner perspectives into conservation practice, and enhancing private landowner cooperation in proactive planning.

Impacts

Vernal pools, designated as Significant Wildlife Habitat under Maine's Natural Resource Protection Act, are critical habitat for many aquatic organisms, but may be used differently in disparate environmental settings. The importance of landscape context in pool-breeding amphibian habitat choice has important implications for conservation. This research project provides science-based information to facilitate the regulation and conservation of amphibians with complex life histories in Maine's diverse geographic landscapes, while allowing for economic growth and development. Our research serves to inform the Maine Department of Inland Fisheries and Wildlife, a primary stakeholder, about potential regulatory disconnects between Maine's diverse landscapes, as well as promote sustainable science to support both healthy ecosystems and strong economies.

Funding

- National Science Foundation, Maine EPSCoR award EPS-0904155 (SSI).

Yellow-spotted salamander (photo Pamela Wells)

Wildebeest Forage Acquisition in Fragmented Landscapes under Variable Climates and Development Scenarios

Randall Boone, Robin Reid, Robert Lilieholm, Michelle Johnson, Spencer Meyer, Jeffrey Worden, Steven Sader, Joseph Ogulu, Jared Stabach, Jesse Njoka, David Nkedianye, Mohammed Said

Objectives

Kenya's Athi-Kaputiei Plains (AKP) cover over 2,590 km2 of rolling plains that once supported the migration of wildlife populations second in size to only the Mara-Serengeti ecoregion (Gichohi et al. 1996). Nairobi National Park covers a small portion of the AKP system, but serves as a crucial reserve for wildlife during the dry seasons. The Park is fenced on three sides and bordered to the north by Nairobi – one of the largest and fastest-growing cities in Africa (Mundia and Aniya 2005). Nairobi's population has increased from 500,000 people in 1970 to over 3 million today (Mundia and Aniya 2005). This growth has been characterized by residential and commercial expansion and intensified land use. With limited land use planning, growth has outpaced infrastructure and human services to create large slums and unplanned settlements in peripheral areas. Unplanned growth combined with physical constraints and mounting environmental impacts threatens the sustainability of both human and natural systems. These threats include the viability of urban centers and traditional Maasai pastoral livelihoods, as well as broader landscape-level processes such as globally significant wildlife migration patterns (Figure 13) (Mundia and Aniya 2005).

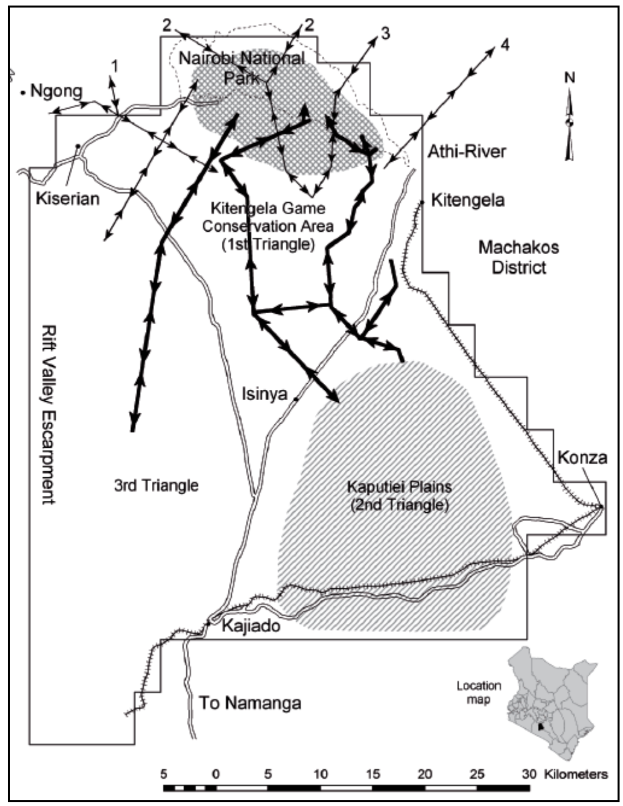


Figure 13. Historic (thin solid lines and arrows, numbered) and current (bold solid lines and arrows) wildlife and livestock grazing routes. Migratory species like wildebeest form a critical link in the ecosystem's food chain.

Hypotheses

H_1: Wildebeest will be more sensitive to fragmentation under increasing variability in inter-annual precipitation

> In landscapes with stable climatic patterns, ungulate populations can be constrained by forage production, or some other capacity. Fragmentation can reduce the movement of individuals and limit their forage acquisition, or force animals to feed longer or in less hospitable places to acquire the same forage. However, assuming the population is finding adequate forage, it will continue to do so year-to-year, given the stability in primary production. In contrast, wildlife mortality from droughts in fragmented landscapes may be extreme if animals are unable to move to areas of ephemeral forage production or to key resource areas such as swamps and hillside grasslands that provide forage over long periods. More fragmentation may accentuate the effect of droughts on vegetation through sustained grazing, and leave forage elsewhere unused.

H_2: Wildebeest in areas of intermediate productivity will be more sensitive to fragmentation than in areas of very low or relatively high productivity

> Wildebeest inhabiting areas of low productivity may, in variable climates, have population dynamics that are loosely linked with primary production. Animal populations in these systems are buffeted by drought, and have insufficient time to recover to approach a forage-based capacity before another drought occurs. Animals in such systems must travel long distances to acquire sufficient forage, such that travel costs to access all the resources the animal may need are maximized. In such cases, isolation of landscapes at scales broader than the scale at which wildebeest move may not cause changes in forage acquisition. In contrast, wildebeest in highly productive areas may need to travel only short distances to meet their daily requirements. Fragmentation in such productive habitats will only affect wildebeest through habitat loss, rather than limiting their movements. It is in areas of intermediate productivity that we expect to see wildebeest populations most closely linked with habitat isolation.

Approach

Our methodology has three major components, which link together to address our hypotheses: (1) the movements of wildebeest must be tracked; (2) fragmentation in the study areas must be mapped and future fragmentation projected; and (3) the success wildebeest have at acquiring forage must be related to fragmentation and climate variability. Movements of animals under different fragmentation regimes will combine with literature on wildebeest habitat use to inform a simulation model of wildebeest movements. Maps of past, current, and future fragmented landscapes plus changes in primary productivity associated with climate variability, will be inputs into a factorial analysis using the simulation model, which will quantify changes in simulated wildebeest populations under different conditions.

We are using agent-based models of wildebeest migration behavior and remotely sensed change detection techniques together with logistic regression models to integrate spatial data and socio-economic and ecological variables in order to model alternative future landscapes to enhance the sustainability of human and natural systems (Marcot et al. 2006). We will identify relevant variables by engaging experts and a broad range of stakeholders in the research process through focus groups and other meetings. Stakeholders will identify biophysical metrics that can be used to identify common site characteristics suitable for wildlife and livestock, as well as areas suitable for commercial and residential development.

We will use these techniques to examine similar development patterns around the Maasai-Mara, Amboseli, and Samburu National Reserves. While drivers of development in these areas are different (e.g., ecotourism-related development vs. urban sprawl), the consequences for wildlife may be the same without effective land use planning.

Results

Urban development has grown substantially since 1984 (Figure 14). Consequently, historic northern migration routes for wildebeest (Figure 13) have been essentially severed by Nairobi and surrounding settlements. The southern migration path, which contains AKP, is bisected by two major roads that create what the community calls the "three triangles" – Kitengela, Athi, and the Kaputiei Plains. These roads represent corridors of rapidly changing land use patterns thought to be driven by changes in land tenure, urban sprawl, and increasing human populations. These changes also threaten the long-term viability of pastoral livelihoods practiced by the region's indigenous Maasai people.

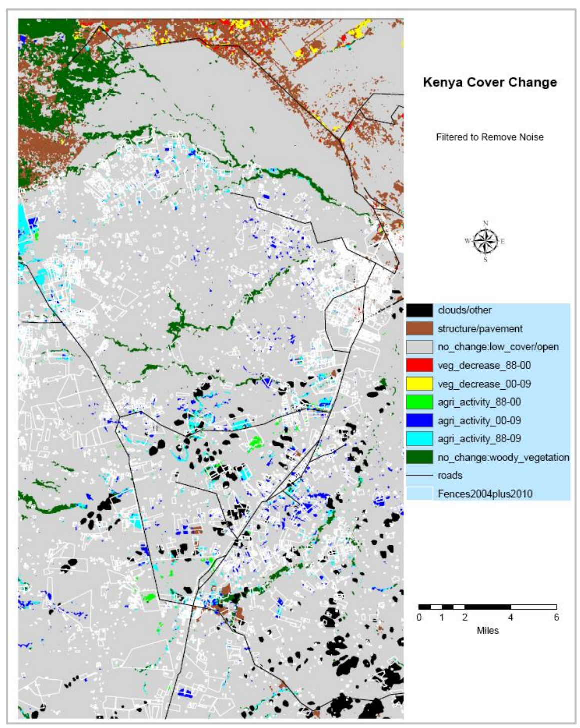


Figure 14. Landscape change in and around Nairobi National Park, 1988-2009.

Thus far, 36 wildebeest have been collared with GPS trackers across our three study areas (see project website, Gnu Landscapes, at *www.nrel.colostate.edu/projects/gnu/*). In-depth analyses of wildebeest movement are still pending, but differences in the movements of wildebeest in our three study areas, corresponding to three levels of landscape fragmentation, are evident. The movements of animals in Amboseli are compressed, and regular. Requirements for animals in this relatively unfragmented landscape are nearby. Animals move from wet season grazing areas directly to key resource areas and water sources, with movements quite regular. In the Loita Plains and Maasai Mara region, the landscape is moderately fragmented. All animals seem to move great lengths (e.g., 2000 km/yr), but some do so while roaming over large areas, while others move within a confined home range. Most intriguingly, animals in the highly fragmented Athi Kapatuei Plains south of Nairobi National Park move much less than those in the other areas (Figure 15). Moreover, wildebeest appear to be avoiding crossing major roads. Our team will analyze the collar data in depth to address this question, given the recent focus on the road proposed to cross northern Serengeti National Park.

Moreover, wildebeest appear to be avoiding crossing major roads. Our team will analyze the collar data in depth to address this question, given the recent focus on the road proposed to cross northern Serengeti National Park.

A set of five future fencing and development scenarios have been created and are undergoing review by our Kenyan partners (Figure 16. A-E). These 2030 scenarios include: (1) trend; (2) trend with smart growth development; (3) increased development; (4) increased development with smart growth; and (5) increased growth with the inclusion of a proposed major highway corridor directly south of Nairobi National Park. Once vetted, these scenarios will be linked with the agent-based models of wildebeest migration to evaluation the sustainability of remaining wildlife migration corridors.

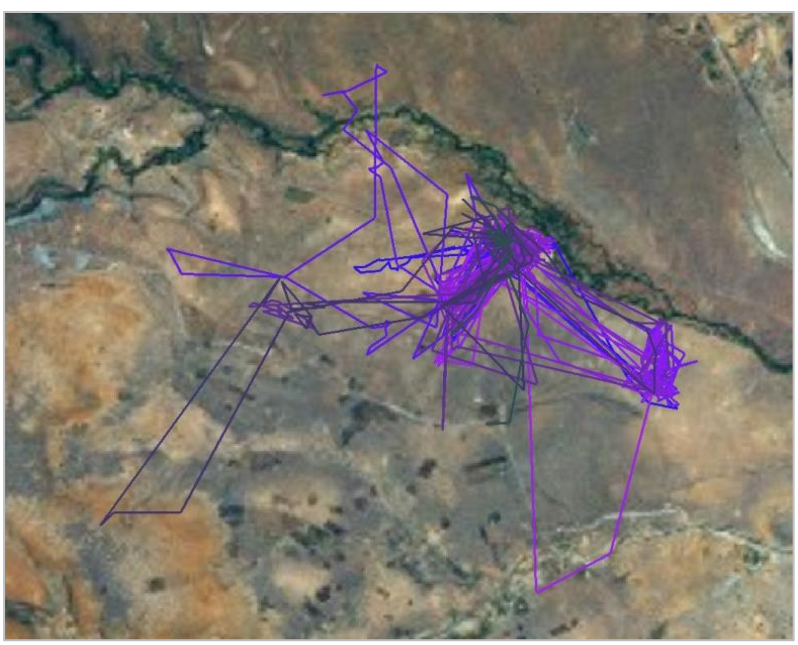


Figure 15. Hourly GPS locations of a collared wildebeest on the southern border of Nairobi National Park, Kenya.

Impacts

Six percent of Kenya is in protected status (Groombridge and Jenkins 2002), but three-quarters of wildlife in Kenya are outside protected lands (Western and Pearl 1989, Western 1998). Our research will quantify the level of land use intensification that promotes support for both human needs and conservation of the dominant migratory ungulate in East African rangelands, now and under future climate change. The Kenya-based team has been working with the AthiKaputiei Plains, Amboseli, and Mara Ecosystems for 12 years on issues including poverty alleviation, livestock production, land use, and wildlife conservation. For this work, the team won first place in a competition of teams around the world working to make science useful for local communities in December 2006. We will contribute to broader societal goals by providing critical information to local and national policy processes in Kenya, and will train community members and students. A report detailing our results will be provided to the Kenya Wildlife Service, the Friends of Nairobi National Park, the Kitengela Ilparakuo Landowners Association, Councils for the group ranches that surround the conservation areas, and the Narok and Kajiado District Councils. Local community members and protected area managers will be involved in every stage of the field work, as employees or stakeholders. We will ask them to continually interpret our findings and update their community members and management colleagues. The issues facing Kenyan arid lands may be more extreme than most ecosystems in the U.S. and the rest of the world, but they are analogous. Our results will suggest pathways for decision making in other parts of the world.

Funding

- National Science Foundation ($688,000)
- Planet Action. 2010. Projecting Land Cover Change and Future Impacts on Wildebeest Migratory Pathways. SPOT Image Corporation and ESRI in-kind donation of high-resolution imagery (Stabach, Lilieholm, Boone, Reid, Worden, McCloskey,) $20,000.
- The University of Maine. 2011. A Proposal to Develop Natural Resource-related Research and Educational Linkages in East Africa. UMaine School of Policy and International Affairs International Travel, Research and Collaboration Grant. $4,565.

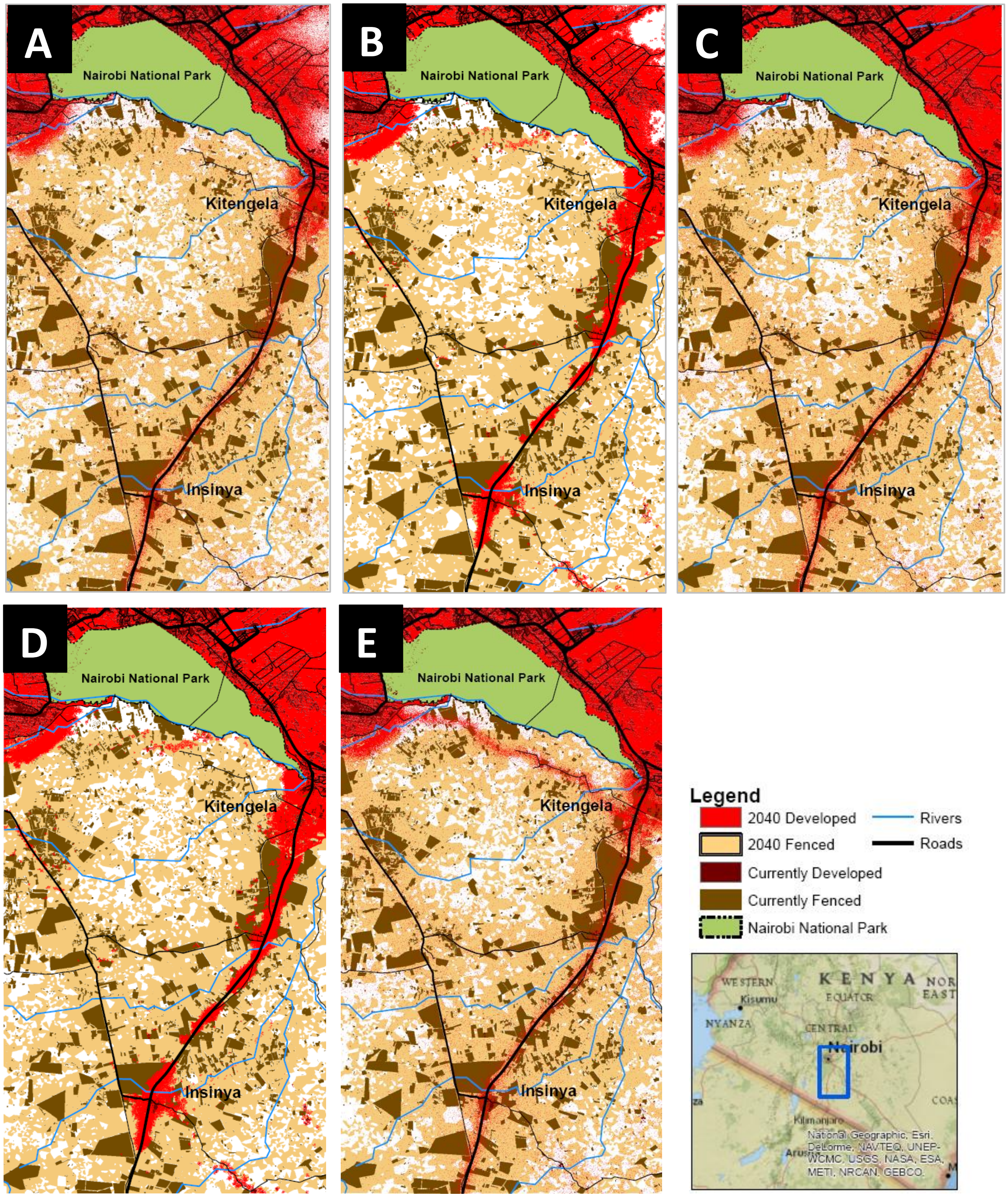


Figure 16. Projected development and fencing by 2040 in the region south of Nairobi National Park under five alternative futures scenarios. A: Trend; B: Trend with Smart Growth; C: Increased development; D: Increased development with Smart Growth; E: Increased development and new highway.

Literature Cited

Gichohi, H., C. Gakahu, and E. Mwangi. 1996. Savannah Ecosystems. P. 243-270 in T.R. McClanahan, and T.P. Young, eds., East African Ecosystems and their Conservation. Oxford University Press, Oxford, UK.

Goodwin, B.J. and L. Fahrig. 2002. Effect of landscape structure on the movement behavior of a specialized goldenrod beetle, Trirhabda borealis. Canadian Journal of Zoology 80:24-35.

Marcot, B., J. Steventon, G. Sutherland, and R. McCann. 2006. Guidelines for developing and updating Bayesian belief networks applied to ecological modeling and conservation. Can. J. Forest Res. 36:3063-3074.

Mundia, C., and M. Aniya. 2005. Analysis of land use/cover changes and urban expansion of Nairobi city using remote sensing and GIS. Int'l. J. Remote Sensing 26:2831-2849.

Western, D. and M. Pearl. 1989. Conservation without parks: Wildlife in the rural landscape. In: Western D and M. Pearl (eds.) Conservation for the Twenty-First Century. Oxford University Press, New York, USA. Pp. 158-165.

Western, D. 1998. Letters to the Editor. Science 280:1507.

Acadian Internship in Regional Conservation and Stewardship

Large landscape conservation training and service for the next generation of public, private and non-profit conservation leaders

Robert J. Lilieholm, James N. Levitt, and Yvonne Davis

The second Acadian Internship in Regional Conservation and Stewardship took place in July and August of 2012. This innovative program combines formal coursework, offered for credit through the University of Maine's Summer University, with a four-week paid internship program hosted across the Downeast Maine and southwest New Brunswick region.

Students and leaders of the Acadian Internship gather at Schoodic Education and Research Center.

Coursework was held at the Schoodic Education and Research Center (SERC) in Acadia National Park. Dr. Rob Lilieholm of the University of Maine's School of Forest Resources coordinated an intensive week of coursework in conservation theory, tools, and methods. A diverse set of nearly 25 faculty, local experts, and guest lecturers – including field trips and case studies within the region – exposed students to the environmental challenges within the region. During the following four weeks, Interns worked with a variety of field sponsors, gaining meaningful, hands-on internship experience. Afterwards, interns reconvened at SERC to place what they learned in their field experience within the greater context of large, landscape-scale conservation. Interns then presented formal project presentations to all stakeholders.

The program's 2012 class of 16 students included a mix of graduates and undergraduates majoring in natural resource-related programs at American institutions ranging from Yale to St. Lawrence College and the University of New Hampshire. Also included were nine overseas Interns from Europe, South America, Africa, and the Middle East. Intern sponsors for the four-week field component included the Maine Coast Heritage Trust, Frenchman Bay Conservancy, Marine Environmental Research Institute, Maine Sea Grant, Downeast Lakes Land Trust, and the Downeast Salmon Federation. One 2011 Intern from Belize returned this year to assist with the course, and an environmental science major from Princeton served as a course assistant for the entire 6-week period.

During the summer of 2013, 16 students from the U.S, Belize, and Chile will work with Lilieholm and Cronan's Alternative Futures Project (see description in this report) to brainstorm ways to transfer scientific knowledge gained through that project into on-the-ground action within the Lower Penobscot River Watershed.

The Acadian Internship is sponsored by the University of Maine, the Quebec-Labrador Foundation, the Schoodic Education and Research Center located in Acadia National Park, and others.

Acadian Interns took to the water to see first-hand some of the important coastal conservation issues.

Commercial Forests: Cooperative Forestry Research Unit

Since 1975, the Cooperative Forestry Research Unit (CFRU) has been working with Maine's large landowners and forest industry to solve the most pressing challenges of forest management, wildlife, and biodiversity.

The Cooperative Forestry Research Unit (CFRU) is the oldest program in the CRSF. Founded in 1975 by leaders from Maine's forest industry, the CFRU is a partnership between Maine's landowners, forest managers, wood processors and conservation organizations. Together, the CFRU partners work together to improve our understanding about Maine's forests and how best to use them for all of society's values. With 35 member organizations and their more than 8.2 million acres as a living laboratory, the CFRU aims to provide information needed to solve the most pressing issues facing the managers of Maine's forests regarding silviculture, wildlife and biodiversity.

This year, the CFRU raised $551,217 in member contributions and leveraged an additional $361,996 in extramural grants and in-kind support. Research highlights from the past year include studies on commercial thinning and regeneration, response of young hardwood stands to management, improvements to growth and yield models, spruce budworm impacts using a decision support system, productivity and costs of harvesting machines, spruce grouse habitat in managed stands, and monitoring of snowshoe hare and Canada lynx populations. The following reports are abstracts from current and recently completed CFRU projects. More information about these and other projects can be found in the 2012-13 CFRU Annual Report on the CFRU website.

35 Members with 8.2 Million Acres

Appalachian Mountain Club
Baskahegan Corporation
Baxter State Park, Scientific Forest Management Area
BBC Land, LLC
Canopy Timberlands Maine, LLC
Clayton Lake Woodlands Holding, LLC
EMC Holdings, LLC
The Forestland Group, LLC
Field Timberlands
Finestkind Tree Farms
Forest Society of Maine
Frontier Forest, LLC
Huber Engineered Woods, LLC
Irving Woodlands, LLC
Katahdin Forest Management, LLC
LandVest
Maine Division of Parks and Public Lands
Mosquito, LLC
The Nature Conservancy
New England Forestry Foundation
North Woods Maine, LLC
Old Town Fuel and Fiber
Plum Creek Timber Company, Inc.

Prentiss and Carlisle Company, Inc.
ReEnergy Holdings, LLC
Robbins Lumber Company
SAPPI Fine Paper
Seven Islands Land Company
Simorg North Forest, LLC
Snowshoe Timberlands, LLC
St. John Timber, LLC
Sylvan Timberlands, LLC
Timbervest, LLC
UPM Madison Paper
Wagner Forest Management

West Lake area, Maine (photo Pamela Wells)

Commercial Thinning Research Network

Brian Roth, Robert Wagner, Robert Seymour, Aaron Weiskittel, and Spencer Meyer

The Commercial Thinning Research Network (CTRN) was established by the Cooperative Forestry Research Unit (CFRU) in 2000 and continues to grow. This network was originally established with the goal of providing information about how spruce-fir stands that have or have not been pre-commercially thinned (PCT) respond to various forms of commercial thinning (CT). Study sites that have had PCT are used to examine responses due to CT timing and relative amount of removal, while those without PCT are used to examine responses due to CT method and relative amount of removal. Recently, the network has expanded to over 18 experimentally controlled study sites across the state. Results from the network are being used to improve growth and yield models for Maine's forests. Several of the following projects have been made possible because the CFRU continues to manage the long-term CTRN experiments.

Funding

- CFRU: $60,133
- Center for Advanced Forestry Systems: $70,000 (two projects described later)

CFRU summer measurement crew at the Penobscot Experimental Forest Commercial Thinning Research Network site (Brian Roth photo).

Response of Tree Regeneration to Commercial Thinning in Spruce-Fir Stands

Matthew Olson, Spencer Meyer, Robert Wagner, and Robert Seymour

Abstract

Traditional silvicultural thinning is implemented to boost growth and final yield of crop trees with no specific intention of triggering a regeneration response. However, there is some reason to anticipate that thinning will initiate some tree regeneration. The goal of this project is to increase our understanding about the influence of commercial thinning on the development of viable regeneration in Maine spruce-fir stands. This project piggybacks on the Commercial Thinning Research Network and evaluates regeneration patterns ten years following thinning to various levels, with and without a previous pre-commercial thinning treatment (PCT). Results show that thinning increases regeneration density over non-thinned stands and that the benefit increases with increasing intensity of thinning.

Funding

- NSRC: $ 3,000

Summer field interns identify and count seedlings in a regeneration plot (Spencer Meyer photo).

Growth and Development of Maine Spruce-Fir Forests Following Commercial Thinning

Robert Wagner, Patrick Clune, Aaron Weiskittel, Robert Seymour, and Spencer Meyer

Abstract

A MS thesis was produced and successfully defended by Patrick Clune who is using the Commercial Thinning Research Network (CTRN) to study Commercial Thinning (CT) response in stands that have and have not received an earlier pre-commercial thinning (PCT) treatment. In stands that had a PCT treatment the questions involved the timing of the CT entry and the relative amount of volume removed. Where PCT had not been applied, the questions involved the CT method and relative amount of removal.

Final results from the spruce-fir stands that had received an earlier PCT demonstrated that all levels and timings of CT entries substantially increased stand growth and improved stand structure relative to the no CT option. However, timing and amount of CT removals interacted when financial objectives were considered. For example, removing a third of the relative volume in an early CT entry increased financial returns; removing half the relative volume in a delayed CT decreased cumulative stand value and net present value (NPV).

In the case of spruce-fir stands that had never received PCT, results indicated that method of CT was critical to stand structure and growth both in the short and long-terms. For example, a low thinning (i.e. removing smaller trees in an overstocked stand) improves stand structure, increases total and merchantable volume PAI, and increases financial returns (NPV) over the no CT option. However, removing the largest and more valuable trees in dominant thinning severely degrades stand structure, substantially increases wind losses, and decreases subsequent stand growth.

At the tree level, CT resulted in increased diameter growth and decreased crown recession on individual trees. The ratio between the height and diameter of individual trees is important to their stability; height diameter ratios (HD) over 100 are susceptible to wind throw. Only the thinning from below method produced residual trees with favorable height diameter ratios in stands that had not had PCT. All CT treatments maintained favorable height diameter ratios in stands that had PCT treatments. Both fir and red spruce respond similarly to CT treatments.

Prentiss and Carlisle. Dow Road CTRN treatment block from the air in September, 2011(Kevin Dow photo).

Funding – $35,000 CAFS

Effects of Non-Selective Partial Harvesting in Maine's Working Forests

Ben Rice, Aaron Weiskittel, Jeremy Wilson, and Robert Wagner

Abstract

Over the past 20 years forest management in Maine has shifted to a heavy reliance on partial harvesting practices. Partial harvesting includes selective methods, such as shelterwood, group selection, and single-tree selection, and also non-selective methods that remove timber within and adjacent to trails, typically leaving a matrix of non-harvested areas between trails. There is a need to better understand post-harvest stand dynamics in these stands. To this end, a study is underway which examines post-harvest stand attributes, such as residual stand density, basal area, volume, and tree damage. Preliminary results indicate a high level of variability among stands in all of these attributes. An analysis of post-harvest growth rates is underway and final results are expected to be available later this year.

Funding:

- CFRU $14,162
- NSRC: $7,000

Typical partial harvest trail several years post-harvest in Maine. (Ben Rice photo).

Refinement of the Forest Vegetation Simulator Northeastern Variant Growth and Yield Model

Aaron Weiskittel, Matthew Russell, Robert Wagner, Robert Seymour, John Kershaw, and Chris Hennigar

Abstract

Forest managers rely on growth and yield models to assess whether their short-term plans will meet long-term sustainability goals. Forest growth and yield models currently in use in Maine, such as the Forest Vegetation Simulator (FVS), were initially built on data from the 1970s and 1980s and often use older statistical techniques. Subsequent tests have shown that these models may not produce the best predictions of how the forests of Maine will grow. As a result, this project was initiated to develop improved allometric and growth equations through the use of an extensive regional database of permanent growth and yield plots. To date, several equations and a site productivity model have been improved and are being evaluated over a range of silvicultural treatments. A beta version of the improved model has been constructed and include a relatively simple software interface which will allow for seamless integration into existing software systems (Figure 17).

Funding

- CAFS: $35,000

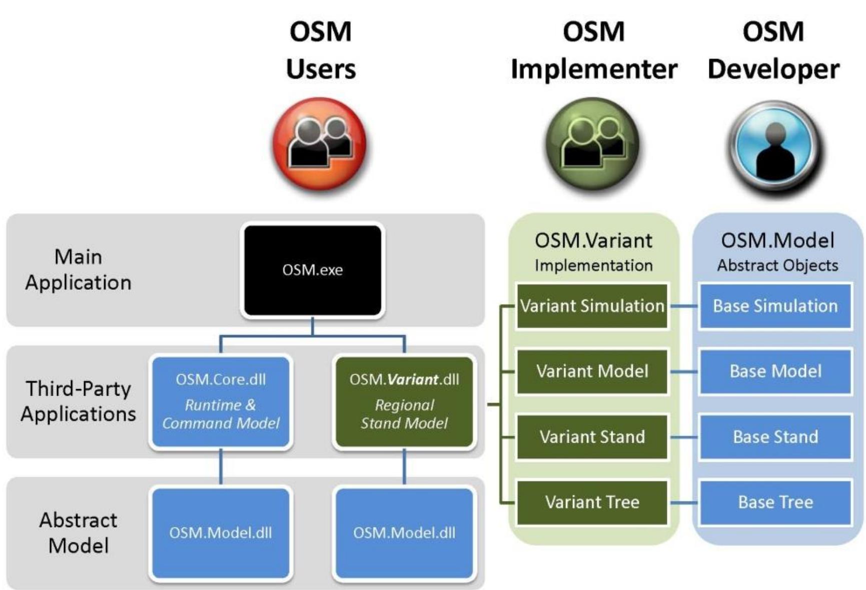


Figure 17. Structure and architecture of the software interface, Open Stand Model (OSM), currently being developed by Dr. Chris Hennigar.

Responses of Young Hardwood Stands to Various Levels of Silviculture and Stand Composition

Andrew Nelson, Robert Wagner, Aaron Weiskittel

Abstract

The overall goal of this project is to refine the prediction of hardwood growth and yield, while incorporating the influence of various intensities of silviculture and species composition. Recently, national biomass equations encompassing all trees species in the US have been developed, but have not been verified for tree species in Maine. In addition, many of the biomass equations available for Maine tree species were developed for trees less than five inches in diameter. In order to evaluate the various approaches, it is necessary to compare the fit of the equations to field data. To this end, data was collected from an experiment on the Penobscot Experimental Forest (PEF) for five naturally regenerated hardwood species (red maple, paper birch, gray birch, bigtooth aspen, and trembling aspen) and compared to the fit of regional and national sapling aboveground biomass equations. Among the four equations investigated, the Jenkins and Young equations overestimated total aboveground biomass of red maple, paper birch, and gray birch, while biomass of these three species was underestimated by the TMK equation (Figure 18). The inability of the national equations to accurately estimate biomass of saplings may pose problems for producing landscape biomass estimates especially for stands dominated by trees less than five inches in diameter and warrants further verification with field data.

Funding:

- $21,958 CFRU
- $14,000 Henry Saunders Chair
- $9,044 NSRC

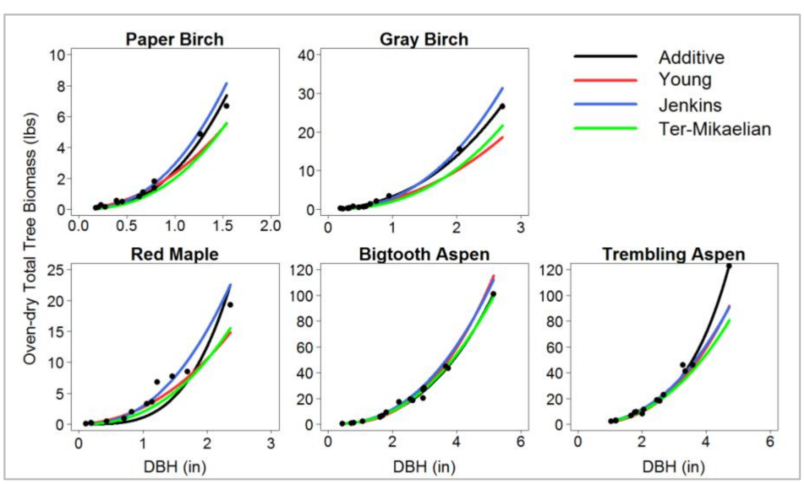


Figure 18. Total aboveground oven-dry biomass (lb.) versus DBH (in.) for the five naturally regenerated hardwood species. Observed data are shown as solid circles, while each of the four lines represents a different biomass equation. The equations are: Additive, Young, Jenkins, and Ter-Mikaelian (TM). Note the difference in the X- and Y-axis values.

The Austin Pond Study:

Third Wave of Silvicultural Treatments

Brian Roth, Robert Wagner, Robert Seymour, Aaron Weiskittel, Derek Brockmann, and Jeffrey Benjamin

Abstract

The Austin Pond Study was established in 1977 by the University of Maine's Cooperative Forestry Research Unit to test the efficacy of seven aerially applied herbicides on conifer release in a regenerating clearcut harvested in 1970. In 1986, each of the original treatment plots was divided in half with one-half receiving PCT. Today, there is an opportunity to extend this study to final rotation by overlaying a series of Commercial Thinning (CT) treatments overtop of the existing design. Working with the variety of forest conditions on the site, five broad types of thinning treatments have been assigned in addition to a "start over" clearcut option. Conifer-dominated plots have been assigned a reduction in relative density of 33, 50, or 66% in conformance with the standards of the Commercial Thinning Research Network (CTRN). Plots with a significantly higher spruce component are assigned a "red spruce release" treatment in which all fir will be removed with the remaining spruce and hardwoods to be thinned to minimum 8-foot spacing. Plots with a hardwood overstory and conifer understory are to receive an overstory removal with a thinning of residual softwoods to minimum 8-foot spacing. All treatments will be controlled and include at least three replicates of at least one acre in size. Implementation started in the winter of 2012/2013 with previously PCT treated experimental units. The non-PCT treated stands will be thinning in the winter of 2013/2014 due to scheduling constraints. Permanent inventory plots have been established to gather data for growth and yield studies. This effort will provide rotation-length measurements on the effects of a wide range of silvicultural options for managing Maine's diverse northern forest.

Harvest notification at the Austin Pond Study Site (Brian Roth photo).

Funding:

- $55,826 CFRU

Spruce Budworm Decision Support and Strategies to Reduce Outbreak Impacts in Maine

Chris Hennigar, David MacLean, and Thom Erdle

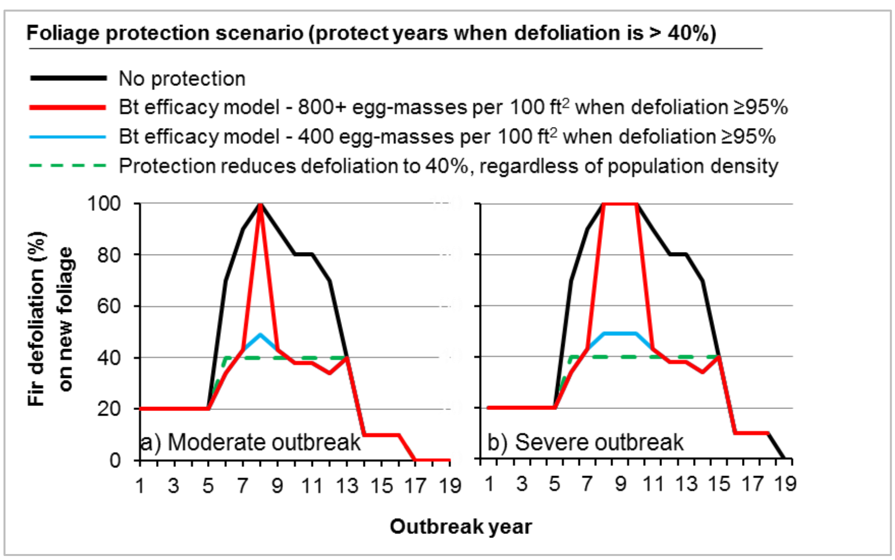
Abstract

Both theory and past experience suggest that another eastern spruce budworm (SBW) outbreak is due across the Northern Forest region. Management of this threat by Maine landowners can be improved by (a) quantifying the potential magnitude of consequences of the next SBW outbreak on wood supplies, land values, and management plans; (b) implementing appropriate harvesting and silviculture in advance of that outbreak to mitigate consequences when it occurs; and (c) having in place a sound decision support system to allocate harvest and protection activities once the outbreak begins. This project calibrated a Spruce Budworm Decision Support System (SBW DSS), originally developed for New Brunswick, throughout the managed forests of Maine. Using this Maine-calibrated SBW DSS, maps of stand merchantable volume impact by various hypothetical outbreak severities were generated. While these scenarios are generalized, they capture the range of potential SBW impacts that may occur in future SBW outbreaks (Figure 19). They have been modeled in the Maine wood-supply impact model and have provided insight into both SBW impacts and mitigation benefits of alternative protection, salvage, silviculture options in Maine.

Funding:

- CFRU: $25,000
- Atlantic Innovation Fund: $5,000

Figure 19. Spruce budworm outbreak and foliage protection scenarios included in the CFRU landowner impact analysis.



Early Commercial Thinning in Maine's Spruce-Fir Forests

Jeffrey G. Benjamin, Robert Seymour and Jeremy Wilson

Abstract

Many of Maine's regenerating clearcuts from the spruce budworm era are dominated by dense spruce and fir saplings less than 6 inches in diameter that have grown beyond the stage where brush-saw treatment is feasible. Such stands are overstocked and would benefit from thinning now, but they are decades away from being operable with traditional harvesting systems due to their small tree size. This research project compared existing whole-tree and cut-to-length harvest systems and trail spacing effectiveness in implementing early commercial thinning in terms of residual stand damage, product utilization, and unit cost of production. Results demonstrated, that from a silvicultural perspective, commercially available equipment exists that can conduct such treatments. However, there are high amounts of residual stand damage across all systems and unit costs are prohibitive given today's market conditions for the raw material. There is a need to continue research in the development of harvesting machines that can cost effectively treat these dense stands.

Funding:

- $11,275 CFRU

A John Deere 1170E Cut to Length harvester at the Early Commercial Thinning Study site in Summit Township, Maine (Jeff Benjamin photo).

Harvest Machine Productivity for Partial Harvests in Maine

Patrick Hiesl and Jeffrey G. Benjamin

Abstract

In 2011 the Cooperative Forestry Research Unit (CFRU) initiated a project to develop cycle time and productivity information for harvesting equipment commonly used in Maine's logging industry for partial harvests. Machine-level productivity data was collected from twelve different harvesting sites throughout Maine from May until August 2012. The data collected for the feller-buncher and processor included the cycle time it takes to cut and/or process each individual tree as well as the cycle time for each feller-buncher head accumulation in combination with the DBH class and tree species. The grapple skidder and forwarder system data collection included a high accuracy GPS unit, used to track the path of the machine during the observation time. Also measured were the number of logs in each grapple and the time it took to load, unload and transport the wood to the landing. Measurements were also taken on the stroke delimber, such as the time to process individual stems, associated by species and diameter. The number of twitches processed was also recorded to estimate average productivity, but the time required to sort biomass was recorded separately. This data is being analyzed and productivity and functions are being generated which will be extremely useful in the forest industry.

Funding:

- CFRU: $55,036

Forwarder collecting wood in a timed trial at the Austin Pond Study (Patrick Heisl photo).

Relationship among Commercial Forest Harvesting, Snowshoes Hares, and Canada Lynx in Maine

Daniel Harrison, Sheryn Olson, David Mallet, Angela Fuller, and Jennifer Vashon

Abstract

Snowshoe hares are a keystone species affecting plant succession, nutrient cycling, and populations of numerous predators and co-existing prey species in northern forest ecosystems. Maintaining an adequate supply of high-quality hare habitat is central to recovery and management efforts for populations of Canada lynx, which are officially designated as threatened in the lower 48 U.S. states and in New Brunswick, Canada. This project documents the relationships among commercial forest harvesting, snowshoe hares, and Canada Lynx in Maine.

Since 2007, inter-annual winter hare densities exhibited a decline in two stand types, regenerating conifer-dominated and selection-harvest stands, whereas mature stand types showed no trend over time. Secondary to this, of interest is whether snowshoe hares use different forest stand types differentially by season in response to changing food and cover resources. Preliminary results indicate hare do not shift activities as much seasonally in mature stands, as compared to selection harvested and regenerating conifer stands. To evaluate the range in dietary diversity that lynx may exhibit in Maine, we collected scats in winter during a period of high relative hare abundance and, conversely, in summer during a period of lower hare abundance. Analyses to determine diet composition in scats is scheduled for spring 2013. It is hypothesized that lynx will shift their home ranges to landscapes with a higher quality of hare habitat during periods of low hare densities. This was investigated using telemetry and preliminary results indicate that lynx maintained home ranges with approximately half of the area comprised of high quality hare habitat during both periods of high and declining hare densities. This long-term collaborative project is nearing completion.

Funding:

- $52,897 CFRU
- $20,000 US Fish and Wildlife Service
- $26, 000 McIntire-Stennis.

A lynx in the snow (David Mallet photo).

Relative Densities, Patch Occupancy, and Population Performance of Spruce Grouse in Managed and Unmanaged Forests in Northern Maine

Daniel Harrison and Stephen Dunham

Abstract

Spruce grouse are dependent on conifer dominated forests and are abundant across Canada and Alaska. However, the southern border of their range intersects only the northern edge of the contiguous United States where a recent assessment by the International Association of Fish and Wildlife Agencies concluded that populations are rare or declining. There is also concern that their habitat, mid-late successional coniferous forests and wetlands, are being harvested at accelerating rates in Maine. The goals of this project are to increase our understanding of the effects of commercial forest management in northern Maine on patterns of habitat occupancy, habitat use, and reproductive success of spruce grouse. Data collection is ongoing and consists of: 1) occupancy surveys in 19 reference stands, 2) home range analysis of spruce grouse broods using radio telemetry, and 3) monitoring of survival and brood rearing success of adult female spruce grouse across a range of stand conditions. The project is scheduled to for completion by December 2014.

Funding:

- $38,500 CFRU
- $2,000 McIntire-Stennis

Captured Spruce Grouse ready to be fitted with a radio collar (Stephen Dunham photo).

Northeastern States Research Cooperative

The Northeastern States Research Cooperative (NSRC) is a competitive grant program, supporting cross-disciplinary, collaborative research in the Northern Forest – a 26-millionacre working landscape that is home to over a million residents and stretches from eastern Maine through New Hampshire and Vermont and into northern New York. The program addresses the importance of the Northern Forest to society and the need for research activities to benefit the people who live within its boundaries, work with its resources, use its products, visit it, and care about it. Funds support a range of research projects that address four themes:

Theme 1 – Vermont

Sustaining Productive Forest Communities: Balancing

Ecological, Social, and Economic Considerations

Theme 2 – New Hampshire

Sustaining Ecosystem Health in Northern Forests

Theme 3 – Maine

Forest Productivity and Forest Products

Theme 4 – New York

Biodiversity and Protected Area Management

NSRC is funded through the U.S. Forest Service Northern Research Station and is a cooperative involving four universities that manage each of the four research themes: University of Vermont (Theme 1), University of New Hampshire (Theme 2), University of Maine (Theme 3), State University of New York (Theme 4). A request for competitive research proposals is solicited annually from research institutions across the four-state region.

Theme Three at CRSF

NSRC Theme 3 is managed by the CRSF. Theme 3 research seeks to quantify, improve, and sustain productivity of the products-based economy of the Northern Forest. Topics include underlying biological processes, management practices, and methods of prediction that will influence future wood supplies and forest conditions. Dr. Bob Wagner and Kae Cooney manage NSRC within CRSF. The following reports showcase the completed and ongoing work by NSRC Theme 3 scientists.

NSRC Final Reports from Prior Projects

Quantifying partial harvest intensity and residual stand composition among stable and changing forest landowner groups in northern Maine

Steven A. Sader

Professor and Director of Maine Image Analysis Laboratory (MIAL), School of Forest Resources, 260 Nutting Hall, University of Maine, Ph. 207 581-2845, Fax. 207 581-2875, E-mail. sasader@maine.edu
Completion date: July 31, 2011

Project Summary

This research utilizes multi-temporal and multi-resolution remote sensing methods to examine differences in harvest intensity and post-harvest stand composition among stable and changing private forest ownership types on unorganized townships in Northwestern Maine.(1.8 million ha). We applied a two-level sampling approach based on satellite change detection and aerial photo interpretation to quantify approximately 14 years of harvest intensity and residual stand composition and density.

A spatial database of private landownership groups (1993-2007) composed of parcels which experienced unique histories of ownership change were combined with time-series harvest maps to develop a sampling frame for photo interpretation. Scanned stereo aerial photos were acquired at 3 time periods (circa 1992/93 – 1997-2007). 725 two hectare stratified random photo sample plots were selected within the ownership groups and visually interpreted to record overstory and understory forest type (S,SH,HS,H), and crown closure percent at pre and post-harvest dates. Significant differences in crown closure percent (indicator of harvest intensity) were observed among forestlands with different landowner change history. Softwood dominant stands had the highest crown closure changes and hardwood species represented higher percentages in post-harvest stands. The methods are applicable to other regions.

Background and Justification

Major land sales among different landowner groups, particularly in the past two decades, along with forest policy changes, have influenced harvesting practices that have shifted from clearcutting in the late 1970s and 1980s to extensive partial harvesting in the late 1990s to present. There are gaps in our knowledge about the intensity of partial harvesting and the composition and density of residual stands in Maine’s privately owned forests. Extensive partial harvesting may lead to landscape level composition and stand structure changes that could affect stand quality, biodiversity, and wildlife habitat for some keystone species.

Ground-based forest measurement data spatially distributed over large regions and multiple ownerships is expensive and time-consuming to acquire. Landsat time-series satellite imagery has proven to be a cost-effective tool to map broad forest types and monitor forest disturbance and trends. Landsat imagery, however, with ¼ acre ground pixel resolution is less capable of quantifying stand density accurately. Photo interpretation has been long accepted in remote sensing research as a tool to map forest type and stand density to support larger landscape mapping studies using satellite imagery.

The research demonstrates a practical approach to combine digital and manual remote sensing interpretation methods using free, public domain satellite and aerial imagery to examine landscape scale patterns of multiple landowner harvest intensity and their effect on residual stand composition and density. The methods are transferable to other northern forest regions and applicable for statewide analysis.

The study area is approximately 1.8 million ha, generally flat to rolling with a few mountains. Forest types consist primarily of spruce (*Picea* spp.), balsam fir (*Abies balsamea*) maple (*Acer* spp.), ash (*Fraxinus* spp.), and northern white cedar (*Thuja occidentalis*) wetlands.

Urban and residential development is minimal. Harvesting is the common disturbance type for this area. Forest ownership types and the recent history of ownership change within this region are broadly representative of the unorganized townships of northern Maine.

Methods

We combined time-series (1993, 2000, 2004 and 2007) Landsat image processing for regional forest disturbance mapping and traditional aerial photo interpretation methods on sample areas to quantify residual stand composition and harvest intensity. Landowner maps (1993/94, 2000, 2004, and 2007) obtained from a private forest engineering company were integrated to define parcels with common histories of forestland ownership.

Preparation of time-series forest harvest and ownership maps provided a sampling frame for aerial photo interpretation of harvest intensity and residual stand condition among different landowner groups. 1 meter imagery from the National Agricultural Imagery Program and the National Aerial Photography Program were processed using Leica Photogrammetry Suite and coupled with a 10m digital elevation map to create ortho-rectified stereo imagery. ArcGIS Stereo Analyst Extension was employed to interpret 725 plots stratified across ownership groups. The photography acquired for

1992/93, 1997, and 2007 provided sufficient temporal depth to assess harvest practices among the major ownerships types, including stable industrial forest products companies, stable family-owned non industrial entities, other non-industrial owners, changing landowners, timber investment management organizations (TIMO) and real estate investment trusts (REIT).

Random samples of 2 ha aerial photo plots in harvested sites were selected from six townships in four ownership groups. Many plots were not interpretable on all dates of acquired photos due to sun glare or low-angled photos and removed from the analysis, giving a final count of 725 plots. Photo interpretation quantifies stand composition and canopy percent cover before and after harvests.

Results

Interpretation of high resolution stereo photo plots from 1997 and 2007 revealedsignificantly higher overstory crown closure removals for forestland that changed from (1) Industrial ownership to TIMO/REIT and (2) from Industrial to Non industrial owners, compared to Stable industrial owners. Other non-industrial is a diverse group of owners, including logging companies interested primarily in shorter term timber extractions, and some conservation organizations with biodiversity goals that de- emphasize short term harvest on much of their lands.

Majority land ownership shifted from primarily Industrial in 1997 to TIMO/REIT by 2007. This trend has been documented in U.S. Forest Service, Forest Inventory and Analysis reports. In comparing ownership type at time of harvest and time since harvest, industrial owners had the largest change in percent overstory crown closure while Old-line non-industrial owners had the least change. Other non-industrial owners maintained the lowest canopy closure before and after harvest. Industrial owner plots which moved to TIMO/REIT owners also experienced an elevated removal of overstory when compared to Stable industrial and Stable old-line owners. Plots with dominant softwood component had the largest changes in percent overstory. However, fewer pure softwood stands were available for harvest (and fewer softwood plots were represented) as a result of the past industrial ownerships that harvested softwood to supply pulp mills. Final results are pending the completion of an MS thesis.

Implications for the Northern Forest Region

It is critical that we develop methods to address the sustainability challenges presented by large-scale natural disturbance coupled with changing forest management practices, ownership, public policy, and market conditions.

The time-series Landsat forest change analysis provides a spatially explicit perspective of harvest, combined with high resolution photo interpretation on photo plots stratified by ownership type provides researchers and policy makers with a landscape level perspective of changing forest composition and structure compatible with regional or statewide analysis.

Results indicated that significant differences in crown closure percent (an indicator of harvest intensity) following harvest were observed among forestlands with different landowner change history. Plots with a predominant softwood had the largest changes in percent overstory and hardwood composition is increasing in regeneration stands following harvest. Extensive partial harvesting may lead to landscape level composition and stand structure changes that could affect stand quality, biodiversity, and wildlife habitat for some keystone species. Similar trends might be expected in other northern forest states where spruce budworm damage was severe, and where major forest ownership changes have shifted primarily from a few large industrial corporations to TIMO or REIT and other non-industrial companies.

Future Directions

In an effort to improve spruce budworm decision support capabilities in advance of the next outbreak, and with support from a NSRC Theme 3 grant (S. Sader –PI) and U. Maine's NSF- EPSCoR Sustainability Solutions Initiative (J. Wilson – PI), we have leveraged the Landsat time-series database to explore broader ecological issues concerning the implications of changing forests on future landscape composition and structure. For example, we coupled field data provided by the USDA Forest Inventory and Analysis (FIA) program with time-series Landsat satellite images to map budworm vulnerability for a 10 million acre northern Maine study area. Host abundance data integrated with forest age maps compiled from satellite-derived time series of stand- replacing disturbance (ca. 1973-2009) have been processed to produce maps of spruce budworm vulnerability.

Two other NSRC projects (K. Legaard and E. Simons – PIs of the separate grants) are using the time-series disturbance data base to research other aspects of landscape scale forest dynamics. Progress on these related research initiatives will be reported by the PIs of the related NSRC projects

Wells Forest, Milford, Maine (Pamela Wells photo)

Restoring American Chestnut and Associated Products to the Northern Forest

Gary J. Hawley[1], Paul G. Schaberg[2]

[1] University of Vermont, Rubenstein School of Environment and Natural Resources, Burlington, VT 05405
[2] USDA Forest Service, Northern Research Station, Burlington, VT 05403

Reporting Period: July 1, 2008 through December 31, 2012

Project Overview

American chestnut (*Castanea dentata* (Marsh) Borkh) was once a prized forest products species throughout the eastern United States. It was the "Swiss Army Knife" of tree species – it "did it all". It was fast growing, unusually large, and produced easily worked, straight-grained wood that was highly rot resistant and useful in a wide range of products. American chestnut was also important to the tannin industry and its yearly mast of nuts was a nutritional mainstay for humans, livestock and wildlife, as well as a source of income for many in the southern Appalachians. About 100 years ago a fungal blight was introduced to the US that rapidly removed American chestnut as an overstory tree. Multiple efforts of restoration of this species have been attempted, yet the one with the most immediate promise of effective restoration involves the hybridization of American chestnut with the highly blight resistant Chinese chestnut (*Castenea mollissima* Blume) followed by repeated backcrosses of resistant offspring with American chestnut. So far, backcross breeding has primarily included American chestnut trees from the heart of the species' former range. Yet, for restoration in the north, the breeding program also needs to identify and include germplasm that provides for growth and survival in colder environments. Indeed, recent research by our laboratory has shown that American chestnuts (both pure native plants and backcrossed stock) are vulnerable to shoot freezing injury and experience winter dieback in the field. Here we propose research to evaluate two methods for bolstering the cold tolerance of American chestnut trees: 1) through the identification of seed sources exhibiting greater cold hardiness, and 2) through studying the influence of overstory silvicultural treatments on the growth, carbohydrate relations, cold tolerance and winter injury of chestnut seedlings. We will establish a series of American chestnut progeny plantings in a replicated design under three levels of silvicultural overstory removal (full, moderate and partial removal) on the Green Mountain National Forest. Seed sources will include genetic lines from throughout the species' range, but emphasize sources from the Northern Forest to more comprehensively detect those sources adapted to northern climates. By replicating the provenance planting over three silvicultural treatments we will be able to assess how genetics, the environment (overstory retention) and genetic x environmental interactions influence cold tolerance and carbon storage (growth and carbohydrate status) of planted stock. Both genetics and silvicultural treatment could influence cold tolerance and growth. Silvicultural treatments could also alter levels of cold exposure that incite injury. In addition to identifying genetic stock and management alternatives that may bolster American chestnut cold tolerance, the plantings established will be a long-term resource for evaluating the influence of genetics and management on American chestnut restoration in the north.

Progress

With the help of volunteer members of The American Chestnut Foundation (TACF), in fall 2008 we acquired nuts of pure American chestnut trees from a wide range of geographic sources as well as Chinese chestnut and red oak seed. In January through March 2009, we conducted a series of laboratory test to measure the cold tolerance of all chestnut and oak seed sources. Analysis of the resulting data showed a gradation in hardiness with Chinese chestnut being the least cold tolerant, red oak the most cold tolerant, and American chestnut intermediate in hardiness. There were also significant differences in hardiness levels among American chestnut sources based on the region of origin and the source within region. In general, sources from the southernmost region were the least cold tolerant. However, significant differences among sources within regions indicate that specific assessment of individual sources is likely necessary for identifying more cold tolerant stock. This study verified that American chestnut nuts have limited cold tolerance relative to red oak acorns (a native competitor in the north), but also highlights that genetic selection could likely be used to enhance the cold tolerance of American chestnut nuts above current species averages.

In a companion portion of this research project, extra nuts from cold tolerance trials were planted in pots at the US Forest Service greenhouse in Burlington, VT in late winter 2009, and seedlings were then outplanted in early June, 2009 into a replicated silvicultural trial on the Green Mountain National Forest in Brandon, VT. We planted approximately 770 seedlings, including pure American chestnut seedlings from 5 northern, 4 mid-Atlantic and 4 southern sources, two sources of Chinese chestnut, and two sources of red oak. Seedlings were distributed in a replicated design under three levels of silvicultural overstory removal (full removal, moderate removal, and a no-removal closed canopy setting). Each seedling was planted with rodent and deer protection (foot-tall vole guards around stems and 4-foot-high deer fences). Temperature measuring devices were randomly deployed with a subset of seedlings per treatment and replicate. During summer 2009 hemispherical photography was used to quantify canopy closure above each seedling (and thereby verify assumed differences in canopy treatment). Seedling size (heights and diameters) were measured soon after planting in the field and then again in fall 2009. Winter injury (terminal shoot dieback) was assessed in spring 2010. The diameter and heights of seedlings were re-measured in fall 2010 and 2011, and winter injury assessed again in spring 2011 and 2012. Cold tolerance and carbohydrate analyses of stem tissues will be conducted once seedlings are large enough to sustain the necessary destructive sampling.

Fritillary moth (photo Pamela Wells)

Refinement of the FVS-NE predictions of individual tree growth response to thinning

Aaron Weiskittel[1], John Kershaw[2], and Laura Kenefic[3]

[1] University of Maine, School of Forest Resources
5755 Nutting Hall, Orono, ME 04469-5755
aaron.weiskittel@maine.edu

[2]jak5280@gmail.com
University of New Brunswick
Fredericton, New Brunswick E3B 5A3

[3] US Forest Service, Northern Research Station
Bradley, ME 04441

Flagged pine tree (photo Pamela Wells)

Completion Date: June 30, 2010
Regional growth model (Forest Vegetation Simulator; FVS) was updated and extended to the Acadian Forest

Project Summary

Regional forest growth and yield models like the Forest Vegetation Simulator (FVS) are designed to project future stand conditions under different management scenarios. However, the current version of the FVS for the Acadian Region is based on historic datasets and traditional statistical techniques, which may limit its accuracy. This project was initiated in 2008 to revise and refine FVS-NE predictions of individual tree growth, particularly in response to thinning. Consequently, an extensive regional network of permanent plot data was compiled and used to refit the primary components of FVS. These equations have been incorporated into an Open Source Model (OSM) software system being developed by Chris Hennigar of the University of New Brunswick. Overall, the model represents a significant improvement to the existing FVS model and will likely see wide application in the Acadian Region.

Background and Justification

- Growth models are widely used for forest planning
- FVS-NE shows significant bias in predictions
- Bias can compound and strongly influence accuracy of long-term projections

Methods

- Compiled and cleaned a regional individual tree growth and yield database
- Over 4 million individual observations from 65 different species
- Range of stand conditions and silvicultural treatments
- Multiple remeasurements 1955 to 2008
- Using compiled database, a variety of species-specific equations were developed
- Nonlinear-mixed effects modeling used
- Equations evaluated and compared to existing FVS-NE equations

Results

- Developed a nonparametric regression model that relates climate to observed site index
  - Explained ~65% of variation using 5 variables
  - Model used to map site index at a 1 km2
  - Can be used to forecast changes in future site index (e.g. Climate-FVS)
- Climate site index was a significant predictors in several component equations
- Of all the component equations, the total height equations showed the highest bias
- Model form and covariates of component equations greatly modified when compared to FVS- NE
- Mortality equations diverged the most from the approach of FVS-NE
- Equations are being inserted into the Open Stand Model (OSM) of Dr. Chris Hennigar of the University of New Brunswick
- OSM is a very flexible interface that links with other third party applications and provides batch mode processing

Implications and applications in the Northern Forest

- Model will be widely used to project future growth and yield under various scenarios and provide different results when compared to the original FVS-NE
- Allow a better understanding of regional variation in growth and yield
- Improved forecasting ability and evaluation of the role of forest management

Future Directions

- Test and verify model predictions
- Improve FVS-ACD ability to represent various factors
  - Management (e.g. thinning, vegetation control, genetics)
  - Spruce budworm
  - Climate change
- Utilize model to forecast future regional wood supply and wildlife habitat

Merging Landsat time-series and FIA data to develop vulnerability maps for spruce budworm defoliation decision support

NSRC Funding awarded July 2009

Co- Principal Investigators

Dr. Steven A. Sader, Professor of Forest Resources, School of Forest Resources, Maine Image Analysis Laboratory (MIAL) 260 Nutting Hall, University of Maine, Orono, ME 04469-5755, Ph. 207 581-2845, Fax. 207 581-2875, E-mail: sasader@maine.edu
Dr. Jeremy Wilson, Associate Professor of Forest Management, School of Forest Resources, 243 Nutting Hall, University of Maine, Orono, ME 04469-5755, Ph. 207 581-9213, Fax. 207 581-2875, E-mail: jeremy.wilson@maine.edu

Co-Investigators

Kasey R. Legaard, Associate Scientist, School of Forest Resources, 116 Nutting Hall, University of Maine, Orono, ME 04469-5755, E-mail: kasey.legaard@maine.edu
Andrew Lister, Research Forester/GIS Analyst, U.S. Forest Service, Northern Research Station, FIA Unit, 11 Campus Blvd, Suite 200, Newtown Square, PA 19073. E-mail: alister@fs.fed.us
Dr. David MacLean, Dean and Professor, Faculty of Forestry and Environmental Management, University of New Brunswick, P.O. Box 44555, Fredericton, NB, Canada E3B 6C2, E-mail: macleand@unb.ca
Dr. Erin Simons, Assistant Scientist, School of Forest Resources, 116 Nutting Hall, University of Maine, Orono, ME 04469-5755, E-mail: erin.simons@maine.edu

Project Summary

The primary goal of this project is to establish methods to predict and map the vulnerability of northern forest stands to spruce budworm defoliation using Landsat satellite imagery and forest attribute data provided by USFS Forest Inventory and Analysis (FIA) plots. Spatial vulnerability models are based on known relationships with host and non-host species relative abundance and forest age, and are used to map vulnerability classes across a 4 million acre study area in northwest Maine. Results are incorporated into an existing spruce budworm decision support system (SBWDSS: MacLean et al. 2001; Hennigar et al. 2007) used to evaluate alternative outbreak scenarios across a 300,000 acre trial area. SBWDSS outcomes are intended to demonstrate the suitability of satellite-derived forest attribute maps for large-scale spatial forest planning.

Summary of Year 3 Progress

To overcome multiple deficiencies of established methods of modeling and mapping tree species distributions, we have developed a novel approach based on advanced machine learning algorithms known as support vector machines (SVMs; Brereton and Lloyd 2010). SVMs are capable of modeling categorical and continuous response variables, enabling a two-stage strategy where species occurrence is first modeled and mapped, and species relative abundance is subsequently modeled at locations where the species is predicted to occur. This approach reduces the negative impact of a large proportion of zero-abundance or low-abundance observations, typical of species with limited distributions. SVMs are capable of modeling highly relationships using a large number of predictors (both continuous and categorical) with limited reference data.

Our algorithms utilize satellite-derived predictor variables as well as ancillary predictors derived from climate, terrain, and soil data. SVMs require the specification of several parameters, and inappropriate parameter settings can have strong deleterious effects. We use a genetic algorithm (GA) to simultaneously parameterize SVM models, select an optimal subset of predictors, and exclude from model calibration reference samples that degrade model performance (based on cross-validation using all samples). Our GA implementation enables the simultaneous optimization of competing model objectives. This allows for the nearly automated specification of models that minimize both prediction error and systematic bias, including attenuation bias.

Our modeling strategy is amenable to the prediction of forest disturbance, and we are working on an adaptation of our software to predict and map disturbance using a time series of Landsat imagery and reference data obtained from the visual interpretation of satellite imagery and aerial photography. Moreover, we are implementing an active learning strategy using our multi-objective GA to minimize reference data requirements. The result is a highly efficient and accurate strategy that discriminates stand-replacing and partial canopy disturbances.

Lastly, we have invested considerable effort in map accuracy assessment. Cross-validation strategies have been applied to all PLSR and SVM models. Validation of stand-replacing disturbance and budworm vulnerability classes has proved to be more difficult. We originally proposed independent field assessments, but the resources required were not supported in our project award. In lieu of a fully independent validation dataset, we have combined FIA plot data with satellite image and air photo interpretations over FIA plot locations to validate maps of stand-replacing disturbance and budworm vulnerability. FIA data are used to identify stand composition and level of maturity. For immature stands, image interpretations are used to date the stand-replacing disturbance that initiated the dominant cohort.

Using Pioneering Growth and Yield Studies to Inform Management and Modeling

Principal Investigators

Aaron R. Weiskittel, School of Forest Resources, 5755 Nutting Hall, University of Maine, Orono ME 04469. aaron.weiskittel@maine.edu

Laura S. Kenefic, U.S. Forest Service, Northern Research Station, 686 Government Road, Bradley ME 04411. lkenefic@fs.fed.us

Cooperators

U.S. Forest Service, Northern Research Station and White Mountain National Forest

Paul Smith's College

Completion Date: May 2011

Summary

Archived, unpublished, and re-measurement data from long-term U.S. Forest Service studies were used to generate new findings about responses to silviculture, inform contemporary forest management, and strengthen modeling efforts in the Northern Forest region.

Funding

Support for this project was provided by the Northeastern States Research Cooperative (NSRC), a partnership of Northern Forest states (New Hampshire, Vermont, Maine, and New York), in coordination with the U.S. Forest Service (http://www.nsrcforest.org) and by the University of Maine, School of Forest Resources.

Project Summary

Despite more than a century of research in the Northern Forest, many forest management questions remain unanswered. The most important include long- term growth response to silviculture, drivers of stand dynamics, and variability of growth and yield. Archives from U.S. Forest Service studies established between the 1920s and 1960s in the northern conifer (previously called eastern spruce-fir) forest type present an opportunity for addressing these research questions. In addition to data from long-term studies at the Penobscot Experimental Forest (EF), we attempted to recover data from the now-closed Finch-Pruyn and Paul Smith EFs in New York, the Gale River EF in New Hampshire, and other studies on commercial forestland in Maine. Incomplete records, data, and metadata from historical studies limited their utility, though some experimental plots were relocated. Ultimately, we used archived, unpublished, and re-measurement data to generate new findings, inform contemporary forest management, and strengthen regional modeling efforts. Key outcomes include documentation of the history of Forest Service research in northern conifers, development of recommendations for record management, new datasets for growth and yield model development and validation, and a focused study of the effects of browsing on northern conifer regeneration and recruitment.

Background and Justification

Though Forest Service research in northern conifers is now primarily conducted on the Penobscot EF in Maine, this forest type was initially the focus of research by the Northeastern Forest Experiment Station (now Northern Research Station). In fact, the first study initiated after the Station was established in 1923 was an investigation of spruce-fir growth and yield. The first EF in the Station was the 1,365-acre Gale River EF on the White Mountain National Forest in New Hampshire; work began there in 1927. Studies directed by Marinus Westveld (the Father of Spruce-Fir Silviculture) investigated the role of partial cutting in establishing softwood regeneration and accelerating the growth of crop trees. The 1938 New England Hurricane destroyed many of the experiments. Though some studies were resurrected, the Gale River EF was disestablished in 1958.

Though the Gale River EF and regional growth and yield plots were the primary sources of northern conifer data in the first half of the twentieth century, another study in this forest type had been established by the Forest Service in 1934: the 623-acre Finch-Pruyn EF in Newcomb, New York. The 2,200-acre Paul Smith's EF was added in 1945 and the two forests were administratively combined under the Adirondack Research Center; research included timber stand improvement, cutting methods demonstration, and a compartment- (or stand-) level study of silvicultural treatments in spruce-fir and mixedwoods. The EFs were disestablished and turned over to Paul Smith's College in 1961.

The 1938 hurricane, aftermath, and World War II motivated Station leadership to reflect on future direction. It was decided that replicated compartment-level studies were desirable. One such study was established in cooperation with forest industry and the University of Maine: the 3,800-acre Penobscot EF in Bradley, Maine. The experiment included silvicultural treatments applied to demonstration areas and approximately 20-acre compartments (management units, MUs); this work has largely continued to the present. In addition to their work on the Penobscot EF, Forest Service scientists conducted a number of growth and yield studies on industry land in the 1950s and 1960s. A regional study of the influence of soils and site on growth of spruce-fir and mixedwoods is of particular interest; measurements of more than a dozen stand, site, and soil variables were made over 10 years.

Methods: Overview

This research was conducted by University of Maine, School of Forest Resources M.S. student Kate Berven under the direction of the PIs. Berven's thesis included three chapters:

1. The lost research of early northeastern spruce-fir experimental forests
2. Sapling recruitment on the Penobscot Experimental Forest: How long-term data can provide information about stand dynamics
3. Seedling herbivory in the Acadian Forest

Chapter 1 reports the history of spruce-fir experimental forests in the Northern Forest, based on literature and archive reviews, and site visits and sampling. Chapters 2 and 3 quantify regeneration and recruitment dynamics using data from long-term silvicultural experiments on the Penobscot Experimental Forest.

Additional work by the PIs related to this study included evaluating long-term predictions by the Northeast Variant of the Forest Vegetation Simulator (FVS-NE), compiling an extensive soil-site study collected in the 1960s, and analyzing trends from a regional dataset collected in the 1970s.

Results: Historical Studies

U.S. Forest Service research records and data from the Paul Smith and Finch Pruyn EFs were found in the basement of a dormitory at Paul Smith's College in 2009. These file have been made available for on-site review and there are plans to digitize the records in the future. Preliminary site visits suggest that while some of the compartments have been harvested, others remain intact and may yield worthwhile remeasurement data.

Some Gale River EF records were found in the attic of a field office in Maine in 2008. The bulk of the files had been sent to the Federal Records Center (FRC); the paperwork needed to recall those has been lost and efforts to locate the files through the FRC were unsuccessful. We visited the former Gale River EF in 2009 and found mortality from a 1980s windstorm, thinning by the White Mountain National Forest, and no field notes or data from the research conducted decades prior. We could not reopen the study, but monumented nine of ten blocks weeding blocks established by Westveld in 1933 and took measurements of species composition and stocking.

Results: Overview

- There is little in the literature suggesting that red spruce is a favored browse species, yet we found a significant impact by hare and rodents
  - 37% of red spruce seedlings were browsed
- Deer populations are high
  - Currently, there are 15-25 deer per square mile in central and southern Maine (Maine IF&W)
  - 25% of northern white-cedar seedlings were browsed
- Browsing should be considered in forest management plans where herbivores are present
- Probability of browsing goes down as height class increases
  - Release treatments may be beneficial in achieving faster height growth on slower growing conifers

Implications: Overview

- Long-term studies
  - Provide valuable information that is difficult to otherwise obtain e.g. Penobscot EF recruitment data
  - Retention and care for records is imperative for future use
- Data from historical studies can be applied to contemporary forest management questions
- Long-term data inform and improve forest growth modeling efforts
- Long-term data are easily lost and require special attention
- Value of long-term will continue to increase with time given that it is properly documented and maintained

Future Directions

- Paul Smith EF archive will be reviewed and digitized.
  - Cutting Practice Level plots may be re-established and re-inventoried, in cooperation with Paul Smith's College faculty.
- Creation of digital archive of Penobscot EF records in underway.
  - Online access to records is a long-term goal; raw data are already available through the Research Data Archive.
- Additional research on species-specific recruitment dynamics, long-term dynamics of browsing, and effect of browsing on competing species (i.e. shrubs and other non-tree vegetation) is planned.
- Regional modeling of forest dynamics is currently be conducted by Co-PI Weiskittel and long-term data such as the Penobscot EF is invaluable for testing model behavior.

NSRC Progress and Final Reports from Current Projects

Silvicultural effects on environmental conditions and resulting above ground productivity and carbon sequestration of northeastern mixedwood forests.

Lead Principal Investigator

Andrew S. Nelson, Graduate Research Assistant, School of Forest Resources, University of Maine, 5755 Nutting Hall, Orono, ME 04473-5755 (phone: 207-581-2763; fax: 207-581-2833; andrew.s.nelson@maine.edu)

Co-Principal Investigators

Robert G. Wagner, Henry W. Saunders Distinguished Professor in Forestry and School Director, School of Forest Resources, University of Maine, 5755 Nutting Hall, Orono, ME 04469-5755 (207-581-4737; robert.wagner@maine.edu)

Michael E. Day, Associate Research Professor, Tree Physiology and Physiological Ecology, School of Forest Resources, University of Maine, 5755 Nutting Hall, Orono, ME 04469-5755 (phone: 207-581-2889; daym@maine.edu)

Ivan J. Fernandez, Professor of Soil Science, Dept. of Plant, Soil and Environmental Sciences, University of Maine, 5722 Deering Hall, Orono, ME 04469-5722 (207-581-2932; ivanjf@maine.edu)

Summary of Progress: FY 2012 – 2013

During the past year, funds for this project have been used to finalize field work and write manuscripts related to the project. In particular, two manuscripts were prepared for publication: (1) the development of hardwood branch, crown, and vertical distribution leaf area models, and (2) light capture, light-use efficiency (growth/light capture), foliar stable carbon isotope composition ($\delta^{13}C$), and aboveground productivity of white spruce growing in naturally regenerated stands and in plantations.

As mentioned in the 2011 progress report, funds for this project were used to destructively sample 91 hardwood trees across a range of diameter. The species sampled included red maple, paper birch, gray birch, bigtooth aspen, trembling aspen, three *Populus deltoides* × *P. nigra* hybrid poplar clones (D51, DN10, and DN70), and one *P. nigra* × *P. maximowiczii* hybrid poplar clone. Trees were sampled from the buffers of the Silvicultural Intensity and Composition (SIComp) experiment plots on the Penobscot Experimental Forest in eastern Maine.

Detailed branch measurements were collected for each sampled tree including branch diameter, branch length, foliated branch length, and branch angle from the vertical. Branches were then subsampled to build branch leaf area equations by scanning, drying, and weighing foliage samples. Branch leaf area equations were fit by species using nonlinear mixed-effects models. The fixed-effects parameters in the model included branch diameter, and relative depth into the crown from the top of the tree. These are the first branch leaf area equations that specify the depth into the crown using the branch tip height and start of the foliage along the branch calculated from branch length and angle. Across the species, branch leaf area was curvilinear from the top of the tree to the base of the crown. Branch leaf area peaked in top third of the crown for paper birch, middle third for red maple and gray birch, and lower third for bigtooth aspen and trembling aspen. Across all four hybrid poplar clones, branch leaf area peaked in the upper third of the crown.

The branch leaf area models were used to predict the leaf area of every branch within each tree, and then summed to obtain total crown leaf area estimates. Crown leaf area equations were then developed for each of the nine species / clones testing various model forms and tree-level covariates. The final models were nonlinear mixed-effects models with diameter at breast height (DBH) and crown length (CL) as fixed-effects, and treatment (untreated control, one-time thinning, thinning + enrichment) as a random effect for the naturally-regenerated species, and clone as a random effect for a single hybrid poplar model. Including treatment/clone in the models did not substantially increase the amount of explained variation. Although crown leaf area was not substantially affected by treatment, differences were found among the species, suggesting that variation in autecological crown traits strongly influence coexistence of hardwood species in naturally regenerated stands following intensive site disturbance. The distribution of vertical leaf area was compared using three continuous distribution functions, including 4-parameter beta, right-truncated Weibull, and Johnson's Sb. The Weibull distribution provided the best fit to the data across species. Leaf area distribution peaked in the middle third of the crown for all species, but slightly higher for red maple and paper birch. This study was unique in that new models were developed to predict leaf area at multiple levels of investigation (branch, crown, vertical distribution) for hardwood species, which tend to have greater crown complexity than conifer species. In particular, this was one of the first investigations to develop leaf area models for shade-intolerant hardwood species in eastern Maine. The manuscript is currently being reviewed for publication in the international journal "Trees – Structure and Function".

Funds for this project were also used to collect the final field measurements of white spruce and neighborhood competitor growth, analyze foliage $\delta^{13}C$, and prepare the manuscript for publication. Light capture of white spruce trees during the 2011 and 2012 growing seasons was estimated using the field measurements of tree dimensions and location, and the detailed, three-dimensional light interception model MAESTRA. Light capture of the individual white spruce trees was adjusted by accounting for light interception by neighboring trees within a 6-m radius, self-shading within the crowns. Seasonal light capture was then compared to leaf area and aboveground oven-dry biomass growth (foliage + woody). We found that aboveground growth was linearly related to both light capture and leaf area. Light-use efficiency (e.g. amount of captured light converted to aboveground biomass) did not vary across the range of neighborhood competition likely because the stands had yet to reach crown closure when differentiation in resource-use efficiency among trees influences competitive sorting. Comparatively, $\delta^{13}C$ decreased with greater neighborhood competition possibly due to lower light capture and associated lower carbon assimilation over the course of the growing season. Overall, the results suggest that in young stands with greater neighborhood competition, aboveground growth and light-use efficiency will likely decline sooner than in plantations due to earlier competitive sorting. This manuscript will be finalized over the next year and submitted for publication. In addition, this paper will be one of the chapters in the Ph.D. dissertation of Andrew Nelson at the University of Maine.

Remaining funds for this project will be used to prepare two more manuscripts. One manuscript will investigate environmental effects on foliar $\delta^{13}C$ of a single hybrid poplar clone. Since genetics may influence physiological processes, using a single clone with identical genetics across a range of growing conditions will allow for detailed exploration of the relation between environmental factors (soil chemistry, soil physical factors) and $\delta^{13}C$. In addition, we plan to analyze a complementary dataset to investigate the influence of neighborhood competition, measured light interception, and soil chemistry on foliar chemistry and aboveground growth of individual white spruce trees in plantations and naturally-regenerated stands.

Pre-commercially thinned softwood stand (photo Pamela Wells)

Response of tree regeneration to commercial thinning in spruce-fir forests of the Northeast

Investigators

Matthew G. Olson, Resource Science Division, Missouri Department of Conservation, West Plains, MO 65677 (matthew.olson@mdc.mo.gov)

Spencer R. Meyer, Center for Research on Sustainable Forests, University of Maine, Orono, ME 04469-5755 (207-581-2872; spencer.meyer@maine.edu)

Robert G. Wagner, School of Forest Resources, University of Maine, Orono, ME 04469-5755 (207-581-4737; robert.wagner@maine.edu)

Robert S. Seymour, School of Forest Resources, University of Maine, Orono, ME 04469-5755 (207-581-2860; rseymour@maine.edu)

Summary of Progress

Since the last report, we have made progress in delivering the final products and outcomes of this project outlined in the 2010 proposal. Aside from the annual progress reports we have provided to date, our communications plan also included: 1) presenting study findings at a forest science conference, 2) presenting the management implications of this study to forest managers at the 2012 biennial Cooperative Forestry Research Unit (CFRU) forester workshop, and 3) publishing at least one refereed journal article. I am glad to report that we have accomplished #s 1 and 2. Spencer Meyer presented the findings of this project at the 2012 ECANUSA Forest Science Conference held November 1-3 in Durham, New Hampshire, which was a great regional venue for this study. Furthermore, we have been accepted to present at the 2013 Society of American Forests National Convention in October. Spencer also presented the results of this project to the CFRU Advisory meeting in October 2012. Building on the preliminary findings summarized in the 2012 progress report, we have developed a manuscript covering the responses of tree regeneration to commercial thinning in Northeastern U.S. spruce-fir stands for submission to a peer-reviewed forest science journal. This manuscript was submitted to the Canadian Journal of Forest Research for consideration as a full-length article on June 10, 2013. Below is summary of project findings presented in this manuscript.

Summary of project findings:

The regional age structure of the Northeastern US spruce-fir forest resulting from 1970-80s spruce budworm infestation, current dominance of partial harvesting methods (Maine Forest Service 2013), and the high level of interest among forestland owners in northern Maine to conduct research about the effects of commercial thinning (CFRU 2006), strongly suggest that commercial thinning will increase substantially in the coming decades. Therefore, knowing what forest regeneration responses can be expected following commercial thinning is vital for foresters and landowners managing spruce-fir stands in the Northeastern U.S.

The goal of this project was to increase our understanding about the influence of commercial thinning on the development of viable regeneration in spruce-fir stands of the Northeastern U.S. during the first decade after treatment. We evaluated understory regeneration on the CFRU's Commercial Thinning Research Network (CTRN).

CTRN is a long-term thinning experiment in Maine investigating commercial thinning treatments in spruce-fir stands with and without a history of precommercial thinning (PCT and No-PCT, respectively). Commercial thinning treatments investigated in this study were: 1) heavy thinning – 50% relative density reduction (RDR), 2) light thinning – 33% RDR, and 3) unthinned control.

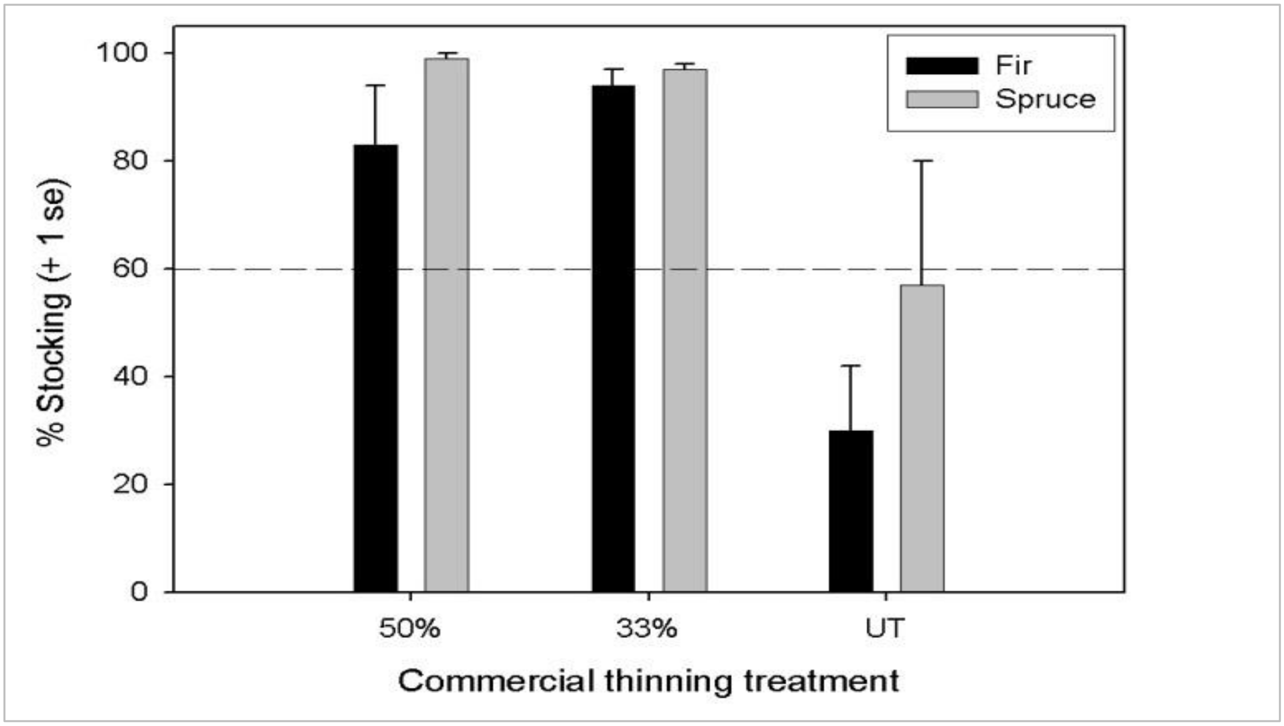
We hypothesized that commercial thinning would increase regeneration abundance and the regeneration density would increase proportionally with increasing thinning intensity. We also anticipated differences in regeneration density and composition among stand types (PCT vs. No-PCT); specifically higher densities of softwood regeneration would occur in older, spruce-dominated stands (No-PCT).

Within a decade of treatment, regenerating densities of spruce, balsam fir, and total softwoods and hardwoods were higher in thinned than unthinned stands, suggesting that commercial thinning increased regeneration abundance. Small softwood (< 2-ft tall) regeneration was greatest in the lighter thinning treatment, while medium (< 4.5-ft tall) and large (< 3.5-in DBH) softwoods increased proportionally with thinning intensity; a pattern that appeared to be related to a higher rate of recruitment in more open stands created by heavier thinning.

Hardwood regeneration density generally exhibited a proportional increase to the thinning intensity and developed into a significant component of the large regeneration size class within a decade of thinning. Softwood regeneration abundance generally was greater in older, spruce stands (No-PCT) than younger, fir stands (PCT), which may be due to greater abundance of advance regeneration at the time of thinning, higher post-thinning residual stand mortality, and/or greater harvest disturbance in older, spruce stands.

However, acceptable softwood stocking, according to regional standards, was achieved in all thinning treatments and two replicates of the unthinned treatment in spruce stands (Figure 20). Therefore, in addition to providing higher individual-tree growth and merchantable yield, commercial thinning in Northeastern U.S. spruce-fir stands also increases regeneration density relative to unthinned stands, and increases the rate of recruitment as thinning intensity increases; thus also providing benefits similar to that of a shelterwood establishment cut.

Figure 20. Mean percentage of plots with at least one softwood tree < 3.5 in. DBH in fir and spruce dominated stands treated with (50% and 33%) and without (UT) commercial thinning within the first decade of treatment. Dashed line at 60% stocking represents a regional standard for adequate stocking (Frisque et al. 1978).



Effects of nonselective partial harvesting in Maine's working forests

Principle Investigator Ben Rice, University of Maine

Current Project Status

The NSRC Theme 3 funded research project "Effects of nonselective partial harvesting in Maine's working forests" is currently proceeding as planned. Minor refinements continue to be implemented to better meet the project objectives. Fieldwork began in 2010 and was completed in 2012. Analysis of the data is ongoing.

Objective 1. Compare post-harvest inventory measurement methods

A list of 250 partially harvested stands within the study area was obtained from the Maine Image and Analysis Laboratory (MIAL). Through analysis of Landsat satellite images these stands were determined to have been partially harvested between 1988 and 2007 with <70% canopy removal. The information provided by the MIAL includes the location, approximate harvest boundaries, and the period of harvest (generally within a three-year period). Twenty-five stands were randomly selected from the list provided by the MIAL and a total of 16 stands were sampled for this objective. Six inventory methods were tested in these stands. Data collection began in summer of 2010 and was completed in 2011. A publication is currently in review with the European Journal of Forest Research.

Objective 2. Conduct preliminary analysis

Due to the richness of the field collected data, we determined an analysis of FIA data is not necessary at this time.

Objective 3. Compare current stand characteristics

Data collection for this portion of the project has been completed and data analysis is currently underway in support of this research objective. A total of 50 stands were sampled and analyses of the data are currently ongoing. Preliminary results suggest that there is substantial variation among partially harvested stands. Complete results for this objective will be produced in forthcoming publications.

Objective 4. Project future stand conditions

Data collected for Objective 3 is being used in projecting future stand conditions. Data analysis for this objective is ongoing.

How Silvicultural Treatments Affect Carbon Storage in a Northern Conifer Forest: A 60-Year Perspective

Weiskittel, A.R., J.C. Brissette, I.J. Fernandez, L.S. Kenefic, R.K. Kolka, and L. Rustad

Reporting Period Covered: 06/30/2012 to 06/30/2013
Outputs: 06/30/2012 to 06/30/2013

Objective

To evaluate the effects of four treatments (reference [uncut since the 1800s], selection cutting [5-year cutting cycle], three-stage shelterwood cutting, and commercial clearcut) on C stored in live trees, deadwood, understory plants, and soils. During the summer of 2012, we measured attributes associated with live trees and deadwood on 105 permanent sample plots across 2 replicates of each treatment. Attributes such as species, diameter at breast height, and decay class were used to estimate biomass from regional regression equations (Young et al. 1980; Harmon et al. 2011). Biomass estimates were then converted to carbon mass by using species and/or decay class specific carbon concentration estimates (Lamlom and Savidge 2003; Harmon et al. 2013). We also collected herbaceous and O horizon samples from each permanent sample plot to determine biomass and C concentration. These results were then used to estimate herbaceous and O horizon C mass on a per area basis. In August - October 2012, we began collecting mineral soil samples within treatments and processed these samples in the laboratory for TC, TN, pH, CEC, and nutrient analysis.

One PhD student is working on the objectives of this project and is completing the second year of his program. Numerous undergraduate students have also been involved in the field and laboratory components of this project. Preliminary results were presented at two conferences, which included C concentration estimates for herbaceous plants, litter, and humus by fines, coarse roots, and buried wood. Prior to this study, little information existed on these estimates for the Acadian forest as well as for other ecosystems. We are also collaborating with researchers at the University of Minnesota and Forest Inventory and Analysis unit to refine our deadwood C content and concentration estimates.

References

Harmon, M. E., B. Fasth, C. W. Woodall, and J. Sexton. 2013. Carbon concentration of standing and downed woody detritus: Effects of tree taxa, decay class, position, and tissue type. *For. Ecol. Manage.* 291: 259-267.

Harmon, M. E., C. W. Woodall, B. Fasth, J. Sexton, and M. Yatkov. 2011. *Differences* *between standing and downed dead tree wood density reduction factors: A comparison across decay classes and tree species*. Res. Pap. NRS-15. USDA For. Serv., Northern Res. Station. 40 p.

Lamlom, S. H., and R. A. Savidge. 2003. A reassessment of carbon content in wood: variation within and between 41 North American species. *Biomass Bioenerg.* 25(4): 381-388.

Young, H. E., J. H. Ribe, and K. Wainwright. 1980. *Weight tables for tree and shrub species in Maine*. Misc. Rep. 230. Orono, ME: University of Maine, Life Sciences and Agriculture Experiment Station. 84 p.

Demeritt Forest, Old Towm, Maine (photo Pamela Wells)

Effects of Climate Change on Growth, Productivity, and Wood Properties of White Pine in Northern Forest Ecosystems

Dr. Ronald S. Zalesny Jr. (Team Leader, Research Plant Geneticist)

U.S. Forest Service, Northern Research Station
Institute for Applied Ecosystem Studies
5985 Highway K, Rhinelander, WI 54501
T: (715) 362-1132; F: (715) 362-1166; rzalesny@fs.fed.us

Accomplishments and Highlights

1. Radial growth analysis of individual tree and site master chronology increment cores from Manistique, Pine River, and Newaygo, MI, Penobscot, ME (n=132), Wabeno, WI, and Turkey Point and Ganaraska, ON were reviewed and re-analyzed, where necessary, to account for presence of false rings, drought rings, etc. (WinDendro software).
2. Field assessment data for height and DBH measurements at all 7 provenance trial locations were reviewed and compiled for analysis.
3. Climate normal data (31 variables) for geographic origin of 12 provenances and 7 planting sites were accessed from http://cfs.nrcan.gc.ca/projects/3?lang=en_CA.
4. Les Groom and his team are conducting the x-ray densitometry work.
5. Conference calls were held, when necessary, to discuss post-sampling processing techniques and plans for reporting and manuscript writing. In addition to the final report, our plan is to produce three manuscripts from the project – the first during the next reporting period (to fulfill project obligations) and the second and third post-agreement.
    a. Growth/mortality related to climate at the test locations
    b. Dendrochronology – radial growth increments of the cores
    c. X-ray densitometry and live-tree carbon
6. Research joint venture agreements that were established in 2011 and 2012 between the University of Maine and the U.S. Forest Service (Zalesny's team), and an international research joint venture agreement that was established in 2011 and modified in 2012 between Zalesny's team and Bill Parker's team at the OMNR were modified with no-cost extensions. In addition, Zalesny maintained an intraregional agreement with John Brissette and an interregional agreement with Les Groom.
7. All reporting requirements have been met.

Priorities for Next Quarter

Our main priority for this reporting period is to finish post-processing of all samples (i.e., x-ray densitometry), analyze data, and begin summarizing data for the final report and manuscripts to:

1. Predict the effects of climate change on growth, productivity, and wood properties of existing white pine forests;
2. Estimate C sequestration potential of white pine under new climate regimes;
3. Quantify range of genetic variation in climatic response and adaptive traits of white pine;
4. Develop seed transfer models from historic climate data and provenance trial data from a subset of test locations;
5. Use validated models from (4) and future climate projections to: a) predict radial and stem growth response of white pine in the northeastern U.S., and b) contribute to provisional seed transfer recommendations for assisted migration of white pine seed sources to help adapt northern forests to future climate.

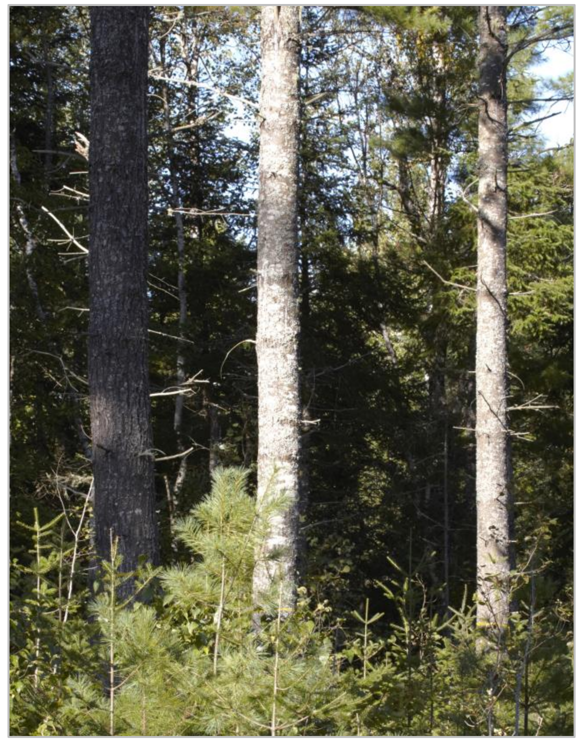
Schedule Status

1. We are on schedule for all tasks and have met all of our obligations for this reporting period, as outlined in the proposal.

Publications and Presentations

1. Given that field sampling was completed during the end of the previous performance period, we are only beginning to generate potential presentations and will work towards publications during the next reporting period (see description of potential publications described above).
2. The following abstracts were presented during this performance period:
    a. Zalesny, R.S. Jr., Bauer, E.O., Birr, B.B., Brissette, J., Colombo, S., Eskelin, N., Froese, R.E., Groom, L., Hall, R.B., Headlee, W.L., Isenhart, T.M., Lu, P., Parker, B., Randall, J.A., Swanston, C.W., Wiese, A.H., Zhu, J.Y. 2012. Ecosystem services associated with purpose-grown *Populus* and *Pinus* in North America. In: 9th Conference of the International Phytotechnology Society: Phytotechnologies – Plant-based Strategies to Clean Water, Soil, Air and Provide Ecosystem Services; September 11-14, 2012; Hasselt, University, Diepenbeek, Belgium.
    b. Zalesny, R.S. Jr., Bauer, E.O., Birr, B.B., Brissette, J., Colombo, S., Eskelin, N., Froese, R.E., Groom, L., Hall, R.B., Headlee, W.L., Isenhart, T.M., Lu, P., Parker, B., Randall, J.A., Swanston, C.W., Wiese, A.H., Zhu, J.Y. 2012. Assessing the environmental sustainability of plantation *Populus* and *Pinus* in North America. In: 9th Biennial Short Rotation Woody Crops Operations Working Group Conference – Woody Crops: Growing a Bioeconomy; November 5-8, 2012; Oak Ridge, TN.

Predicting dynamics of white pine advance regeneration under shelterwood silviculture



White pine stand (photo Pamela Wells)

Lead Principal Investigator

Robert S. Seymour, Curtis Hutchins Professor of Forest Resources (Quantitative Silviculture), School of Forest Resources, University of Maine, 5755 Nutting Hall, University of Maine, Orono, ME 04469; Tel: 207-581-2860, Fax: 207-581-2875, Email: rseymour@maine.edu.

Cooperator

Emma Louise Schultz, Graduate Research Assistant, School of Forest Resources, University of Maine, 5755 Nutting Hall, University of Maine, Orono, ME 04469;
Tel: 651-319-2008,
Fax: 207-581-2875,
Email: emma.louise.schultz@maine.edu

Abstract

In recent decades, eastern white pine (*Pinus strobus* L.) has arguably become the single most important commercial tree species in Maine, perhaps second only to red spruce in commercial value. Managers frequently choose to regenerate white pine through an extended shelterwood system, which best mimics the species' natural regeneration strategies. However, this management is based largely on experienced intuition; specific quantitative targets regarding height growth rates under varying overwood densities, and timing of overstory removal cuttings, are not supported by the published literature. We therefore seek to develop a robust model for understanding and predicting the dynamics of eastern white pine managed under the shelterwood regeneration method.

Study sites will span a soil and environmental gradient across Maine and will be chosen where (a) pine is a dominant forest type, (b) shelterwood establishment cutting has occurred, and (c) there is well-

developed pine regeneration. The understory light environment will be measured directly above saplings across a systematic grid with a LI-COR LAI-2000 (LI-COR, Lincoln, NE) and with digital hemispherical photography. Double light sampling will occur in the lower sapling height classes, allowing for comparison and corroboration between techniques, while only the LAI-2000 will be used for taller saplings that outdistance the camera's tripod. Across the forested stands of interest, we will subsample saplings to equally represent light gradient groupings. With each measured sapling as a respective plot center, we will collect overstory measurements (basal area, height) as well as sapling data (the previous five years of terminal leader height growth, measurements to characterize crown size and shape, and presence of disease and white pine weevil).

Analysis will attempt to predict development of the understory as a function of the canopy by modeling height growth from light, will develop regression equations relating the understory light environment to overstory metrics, and will compare results to a projected output in both FVS-NE variants. The study will conclude with recommendations for future FVS-NE small-tree model calibration for white pine.

Predicting Effects of Even-aged Silviculture On Commodity Production, Carbon Sequestration, and Wildlife Habitat Characteristics In Northern Hardwood Stands

Pileated woodpecker (photo Pamela Wells)

Lead Principal Investigator

Ralph D. Nyland

SUNY College of Environmental Science and Forestry
1 Forestry Drive
Syracuse, NY 13210
315-470-6574
FAX 315-470-6535
rnyland@syr.edu

Co-Principal Investigator

Eddie Bevilacqua
SUNY College of Environmental Science and Forestry

Abstract

This project will revamp and expand an existing stand simulator initially prepared for use with uneven-aged silviculture by developing and substituting growth and mortality functions using response variables pertinent to managed even-aged stands. In addition, it will formulate new functions for forecasting tree and stand structural characteristics commonly used with wildlife habit evaluation, but for single-cohort communities. Existing carbon and wood volume equations will convert tree and stand data to estimates of standing crop and harvested products. Projections by the simulator will describe changes due to a thinning or other intermediate treatments, as well as subsequent production and sequestration for an ensuing time period. Output data will also portray effects on stand structural characteristics, including those related to wildlife habitat elements. The proposed simulator, which will include Monte Carlo methods to account for uncertainty in model predictions, will accommodate a variety of initial conditions and management objectives, and provide

useable output for a single cutting cycle, or a series of them appropriate to a 100-year planning horizon. Once constructed, the simulator will support experiments to compare outcomes from intermediate treatments of different kinds and intensities. The output information will facilitates decisions about managing even-aged northern hardwood stands with respect to sustainable production and yields of wood and carbon, and selected wildlife habitat characteristics. Findings will be summarized as guidelines that decision-makers can use to compare management alternatives, given a specified set of initial set of stand conditions and landowner objectives.

Update

Thesis research into diameter growth and mortality of northern hardwoods in even-aged stands currently completed, by David A. Schmidt. His MSc. Thesis currently in preparation, with a defense date scheduled for September 2013. Findings reveal important differences in radial increment and rates of mortality among trees of different crown positions as reflected by initial diameter of the trees. Growth rates also vary with residual stand relative density. These functions will become part of the even-aged northern hardwood stand simulator currently in preparation as part of the project.

Information from diameter growth assessment developed during the research and appropriate to both even- and uneven-aged stands used as part of nine different workshop presentations related to rehabilitating cutover hardwood stands, Summer 2012 through Spring 2013.

A manuscript related to thesis research by Lindsay Nystrom in preparation. It will report on functions for predicting ingrowth into the 1-inch diameter class for stands lacking or with different levels of understory beech interference. Completion scheduled by late August 2013.

Managing an Aging Resource: Influence of age on leaf area index, stemwood growth, growth efficiency, and carbon sequestration of eastern white pine

Lead Principal Investigator

Robert S. Seymour, Curtis Hutchins Professor of Forest Resources (Quantitative Silviculture), School of Forest Resources, University of Maine, 5755 Nutting Hall, University of Maine, Orono, ME 04469; Tel: 207-944-9534, Fax: 207-581-2875, Email: rseymour@maine.edu.

Progress Report June 30, 2013

The main goal of this study is to quantify the key attributes of the production ecology of eastern white pine over a 200+-year chronosequence, for the purpose of formulating optimal rotations and regeneration strategies for the maturing pine resource of New England. Objectives are to:

1. Quantify the effects of age and stand density on leaf area index (LAI), following the models of Long and Smith (1992) and DeRose and Seymour (2010).
2. Quantify the stemwood and total above-ground productivity (biomass, Carbon) and growth efficiency over this same chronosequence.
3. Compare the patterns documented to those predicted by the Fire and Fuels Extension of the Forest Vegetation Simulator (Dixon 2001).

Data Collection and Analysis

Adam Bland, M.S. Student supported by a SFR Research Assistantship, completed data collection following the proposed methodology during the 2011 field season.

Study design follows a chronosequence approach, with plots ranging in age from 18 to 203 at breast height (Table 4). Plots are pure white pine, and range in density from very open crop-tree thinnings to very high density self-thinning stands. All trees were measured for DBH, total height, and height to the crown base. Trees were double-cored to quantify the sapwood area, which is used to estimate the tree leaf area based on newly fitted allometric equations using data from 64 destructively sampled white pine trees from several past studies. Leaf-area index was estimated by summing tree leaf areas on the plots and dividing by the plot size.

Litterfall has also been monitored for as long as 20 years on most of these plots to provide an independent assessment of leaf area index based on previous estimates of needle retention and specific leaf area ("LAI" column, Table 4).

Mr. Bland successfully defended his master's thesis in December 2012.

Objective One:

To address objective one, various models were tested, and the following model provided the best fit:
LAI = -29.87486 + (-0.13206*TOPHT) + 3.54537*log(TOPHT) +25.41788*log(SI) + 2.55679*log(RD

This equation is plotted in Figure 21. It has the expected properties of a peak LAI at a height of about 20 meters, and increasing LAI with increasing relative density.

Table 4. Summary statistics of long-term litterfall data collected within the Demeritt Forest including stand name, stand ID, dominant breast height age in 2011 (BH Age), relative density (RD), mean height of tallest 40 trees per acre (TOPHT), projected leaf area index values from average of litterfall traps (LAI), site index (SI), year of first collection (First Collection), number of traps per plot, plot size.

Stand	Stand ID	BH Age (2011)	RD	TOPHT (m)	LAI	SI(m)	First Collection	No of Traps	Plot Size (ha)
Unthinned									
1990	F9	18	(0.17-	(5.7-11.4)	(0.8-	21.5	2001	6	0.01
1970	C300	42	(0.61-	(12.5-19.6)	(3.1-	20.3	1996	4	0.01
Control	D32	65	(0.32-	(16.2-24.3)	(2.9-	19.1	1992	20	0.04
HD	D32	65	(0.65-	(15.4-22.7)	(2.5-	19.1	1992	6	0.03
BlueSpr	F12	80	0.93	29.4	4.0	21.4	2011	5	0.04
MM	E24	108	0.94	34.5	2.9	22.2	2010	5	0.04
Nutting	R204	203	0.94	(37-40.7)	3.5-5.0	19.8	2002	5	0.04
Early PCT									
2x2	C65	19	(0.1-	(6.1-12.1)	(1.7-	21	1998	2	0.01
2x2New	C65	20	(0.12-	(7.3-13)	(3.7-	23.2	2002	5	0.01
3x3	C65	22	(0.18-	(11-14.2)	(4.6-	22.8	1998	5	0.01
LightThin									
Old-Field	E132	55	(0.64-	(18.9-25.4)	(3.5-	19.5	1992	5	0.04
Low									
LD	D32	65	(0.15-	(17.1-23.2)	(1.7-	18.7	1992	20	0.04
1970-LD	C300	42	(0.11-	16.3	(0.4-	19.4	2008	5	0.04
B-Line									
B-line	D32	65	(0.23-	(16.1-23.6)	(2.9-	18.7	1992	20	0.04

Although not one of the NSRC Proposal's original objectives, another important contribution of Adam Bland's MS Thesis is the development of a density management diagram (DMD) for eastern white pine based on the chronosequence data. The maximum size-density relationship was estimated using quantile regression at the 99th percentile from equation (4) as:

$\text{Log}\,\overline{Vol}$ = 4.83978-*1.3173**LogTPA

This equation is plotted in Figure 22, and compared to the two other published DMDs for eastern white pine. Importantly, our data allowed a more precise fit over a greater range of densities and volumes, and strongly suggests that the true slope of the maximum density line is less than -1.5 as found by Innes et al. (2005), closer to 1.3. This work has been formatted as a manuscript and will soon be submitted to the Northern Journal of Applied Forestry.

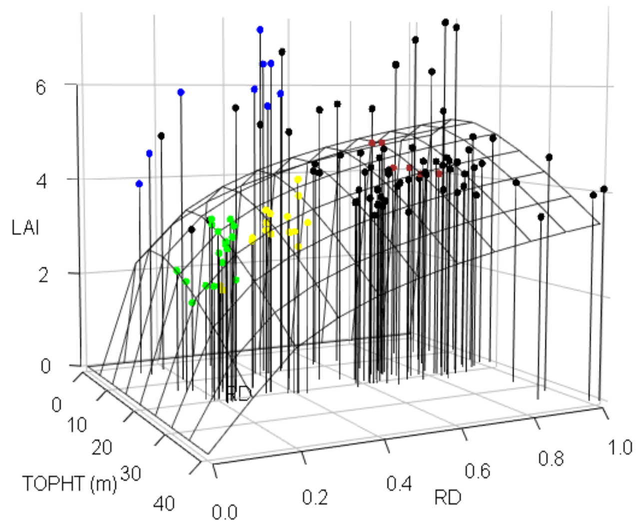


Figure 21. Comparison of maximum density lines constructed for eastern white pine in Ontario and New Hampshire and this study.

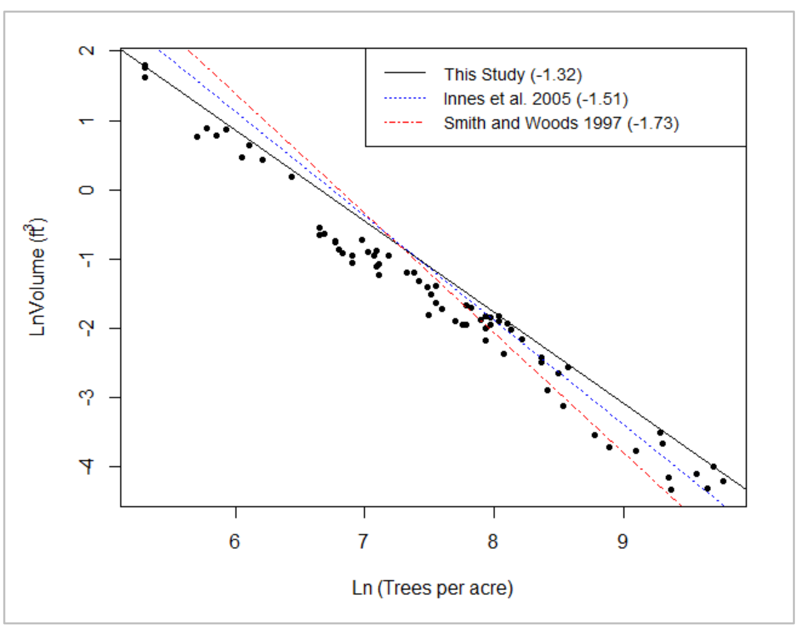


Figure 22. Three-dimensional plot showing leaf area index, stand top height (TOPHT), and relative density (RD). (holding SI = 19.68).

Objectives Two and Three:

Adam Bland's thesis does not address Objectives 2 and 3. Nathan Rutenbeck, Ph.D. candidate working under PI Seymour, has carried out preliminary summaries and analyses of growth and growth efficiency patterns. The attached pdf (RutenbeckGESummary) includes 3 summary panels of (1) Leaf Area Index, (2) total stemwood volume per hectare, and (3) comparisons of volume increment and growth efficiency; these are followed by individual higher-resolution figures of each plot separately. These results are currently being reviewed for accuracy and will be the basis for a synthesis publication on this study.

.

How Silvicultural Treatments Affect Carbon Storage in a Northern Conifer Forest: A 60-Year Perspective

Principal Investigator

Aaron Weiskittel, University of Maine, 229 Nutting Hall, Orono, Maine 04469; Phone: 207 581-2857; email: aaron.weiskittel@maine.edu.

Co-Principal Investigators (alphabetical)

John Brissette, USDA Forest Service, 271 Mast Road, Durham, NH 03824; Phone: 603 868-7632; email: jbrissette@fs.fed.us.

Ivan Fernandez, University of Maine, 1 Deering Hall, Orono, Maine 04469; Phone: 207 581-2932

Laura Kenefic, USDA Forest Service, 686 Government Road, Bradley, ME 04411; Phone 207 581-2794; email: lkenefic@fs.fed.us

Randy Kolka, USDA Forest Service, 1831 Hwy. 169 E., Grand Rapids, MN 55744-3399; Phone: 218 326-7115; email: rkolka@fs.fed.us

Lindsey Rustad, USDA Forest Service, 271 Mast Road, Durham, NH 03824, Phone: 603 868-7658: email: lrustad@fs.fed.us

Abstract

Forest ecosystems can store a significant amount of carbon (C) in various components (e.g. soils, coarse woody debris, living trees, etc.), which can be modified by silvicultural activities. There is great interest in forest ecosystem C due to its implications for climate change and associated mitigation efforts. However, relatively little work has been done on the relationship between forest ecosystem C and different silvicultural approaches in the mixed- species forests of Northeast. Much of the previous work on the subject in the Northeast has relied on statistical growth and yield models like the Forest Vegetation Simulator (FVS) to simulate these relationships, with little understanding of the overall accuracy of the projections. In addition, previous studies have been relatively short-term in nature and only provide a limited perspective on forest and C dynamics. This project seeks to explore the long-term trends in forest ecosystem C due to a wide range of silvicultural treatments implemented at the Penobscot Experimental Forest in central Maine. The

specific silvicultural treatments to be examined include no management (reference), selection cutting, shelterwood cutting, and commercial clearcutting. The analysis will rely on an extensive network of periodically remeasured permanent sample plots that were established in the 1950s. We propose additional field work to supplement the existing database, by intensively measuring C content of downed woody debris, understory plants, and soils. We will develop a complete description of forest ecosystem C and will make comparisons between the silvicultural treatments. Overall, this research will increase our basic understanding of the long-term effects of silvicultural treatments on C dynamics in stands with diverse structure and composition, both in the tree component of the ecosystem (over 60 years) and in all ecosystem components (after 60 years).

Studmill Road,Milford, Maine (photo Pamela Wells)

Evaluating and predicting the regional effects of silviculture and site factors on regeneration in the northern conifer forest

Lead Principal Investigator

Mohammad M. Bataineh, Postdoctoral Research Fellow, U.S. Forest Service – Cooperative Forestry Research Unit, 215 Nutting Hall, University of Maine, Orono, ME 04469, Phone: (207) 581-2856, Fax: (207) 581-2875, mohammad.albataineh@maine.edu

Co-Principal Investigators

Aaron Weiskittel, Assistant Professor of Forest Biometrics and Modeling , University of Maine, 5755 Nutting Hall, Orono, ME 04469, Phone: (207) 581-2857, aaron.weiskittel@maine.edu

Laura Kenefic, Principal Silviculturist, U.S. Forest Service, Northern Research Station, 686 Government Road, Bradley, ME 04411, Phone: (207) 581-2794, lkenefic@fs.fed.us

Ben Rice, School of Forest Resources, University of Maine, 5755 Nutting Hall, Orono, ME 04469, Phone: (207)581-2763, ben.rice@maine.edu

Robert Seymour, Professor of Forest Resources, University of Maine, 211 Nutting Hall, Orono, ME 04469, Phone: (207) 581-2860, rseymour@maine.edu

Cooperators

Michael Saunders, Purdue University, IN 47907, Phone: (765) 430-1440, msaunder@purdue.edu

Executive summary

The goal of this project is to determine whether the composition and abundance of natural regeneration is controlled primarily by overstory conditions created by harvesting, or by other site-specific factors and stochastic events. Funding for this two-year project was awarded in 2012 at a 74,861 level. Awarded funds have remained largely intact by leveraging funds and labor from other sources, with first use of NSRC funds in May 2013. The project next key milestones include completing a regional analysis of

compiled and available data and the development of linear and nonlinear hierarchical generalized regression models to predict the occurrence, frequency, and composition of natural regeneration. Our plans also include the calibration of an expert regeneration model (REGEN) that allows for predicting regeneration using initial regeneration conditions and species competitive ranks.

During the first year of the project we have accomplished the following:

1. Field measurements: were conducted across three existing studies (USFS PEF Silvicultural Study; Acadian Forest Ecosystem Research Program; Non-Selective Partial Harvesting Study)
2. Data compilation and sample processing: data from the three studies were compiled, seedling cross-sections and hemispherical photos are currently being processed
3. Data analysis:
    a. Data collected from two of the existing studies over 2012 were summarized in a Master of Forestry Report (Eben Sypitkowski) and an NSF-Research Experience for Undergraduates student (Tahir Ibrahim) project
    b. Previously collected data from the USFS PEF Silvicultural Study was analyzed for a publication in Forest Ecology and Management
    c. Data collected from the Non-Selective Partial Harvesting Study are currently being analyzed and will be part of Ph.D. Dissertation (CO-PI: Ben Rice)
4. Reporting and outreach:
    a. An overview of the project was presented at a field tour at the Penobscot
5. Experimental Forest 2012
    a. Preliminary findings were reported at the Eastern CANUSA Forest Science
6. Conference, New Hampshire 2012
    a. Trends in natural regeneration abundance and composition were summarized in a
7. Master of Forestry Report (Eben Sypitkowski)
    a. A first look at the effects of silviculture and site factors on natural regeneration was reported in a recently accepted publication in Forest Ecology and Management

Project milestones and future plans:

The next key milestone for this project is to complete a regional analysis of compiled and available data. We have planned on collecting additional data from the Non-Selective Partial Harvesting Study sites this summer (2013). However, we have reconsidered this option in favor of maximum utilization of available data including that of the Forest Inventory and Analysis plots. Our regional analysis will inform the need for additional sampling and may require a request for a no-cost extension of this project beyond the initial two-year period. Our rationale is that of effective and efficient use of resources and capital while simultaneously making meaningful progress toward the development of management guidelines and predictive regeneration models. Our regional analysis will entail the development of linear and nonlinear hierarchical generalized regression models to predict the occurrence, frequency, and composition of natural regeneration.

During the next year we will be working on completing sample and imagery processing, compiling data, and conducting the regional analysis. Our plans also include the use of available funds for the calibration of an expert regeneration model (REGEN) that allows for predicting regeneration using initial conditions and species competitive ranks. Data for the calibration of the REGEN model are available from the USFS PEF Silvicultural Study. We are currently collaborating with Phil Radtke (Virginia Tech) and Tara Keyser (USFS) to achieve this objective.

Crooked River, Naples, Maine (photo Pamela Wells)

Extending the Acadian Variant of the Forest Vegetation Simulator (FVS) to Managed Stands in the Northeast US

Aaron Weiskittel[1], John Kershaw[2], and Chris Hennigar[3]

[1]University of Maine, School of Forest Resources, Orono, ME 04469

[2]University of New Brunswick, Forestry and Environmental Management, Fredericton, New Brunswick E3B 5A3

[3] New Brunswick Department of Natural Resources, Growth and Yield Unit, Fredericton, New Brunswick E3B 5H1

Introduction

Currently, 16,500 acres of Maine timberlands are planted, precommerically thinned (PCT), or treated with herbicide per year, and an additional 500,000 acres per year receive an intermediate thinning entry. Consequently, active forest management is widely practiced in the state and throughout the entire Northeastern region. To better understand the long-term consequences (wood supply and rate of return) of these different activities, improved growth and yield models are needed as existing ones are outdated, poorly maintained, geographically constrained, or limited by an array of additional factors. Based on funding from the NSRC, US Forest Service, University of Maine Cooperative Forestry Research Unit (CFRU) and NSF, the development of an Acadian variant of the Forest Vegetation Simulator (FVS-AD) was initiated and led by Co-PI Weiskittel. A beta version of the model has been constructed and is currently being tested. The goal of this proposal is to extend the FVS-AD to managed stand conditions common throughout the region.

Methods

Based on existing knowledge, an array of plots with various management activities have been determined throughout the region. These plots consist of CFRU and US Forest Service research installations in Maine as well as permanent and temporary sample points in New Brunswick and Nova Scotia. These plots have received varying levels of site preparation (e.g. bedding, ripping), vegetation control (herbicide and conifer release), PCT, CT, and genetic improvement. Several are long-term experimental sites with over 30-60 years of continual periodic measurements. The majority of sites have tagged individual trees with numerous repeated measurements and cover a range of site conditions. The data from the existing plots are being compiled and standardized into a relational database. The database consists of four primary tables including tree measurements (species, diameter at breast height, total height, height to crown base, and status), plot summaries (growth year, standing basal area, basal area harvested, stem density, etc.), management history (type of management, indicators for various management activities, treatment dates, application or removal rates), and site attributes (climate site index, depth to water table, latitude, longitude, elevation, aspect). All tables are being standardized to metric, US Forest Service Forest Inventory and Analysis (FIA) species codes, and ownership information of the original dataset owner is being removed for proprietary reasons. Once the data is compiled and cleaned, the component equations that currently compromise the FVS-AD would be tested using the database. When a component equation is deemed significantly biased, a species- and management-specific modifier function would be developed using the data available for analysis. This modifier function would adjust the predictions of a base FVS-AD component equation to better reflect the different management activities. The final modifiers would be included in the FVS-AD to project the long-term consequence of various planting, vegetation control, PCT and CT treatments in the Acadian region.

Progress

The primary datasets has been identified and compiled into the standardized, relational database. A PhD student for the project has been identified and will start in the fall of 2013. Next year, an assessment of the existing equations on the new data and preliminary development of equation modifiers will be completed.

Deliverables

The project will provide the database and equations to predict the influence of various forest management activities on growth and yield. The base FVS-AD equations and their modifiers developed from this study are being incorporated into an open source dynamic link library (DLL). An additional wrapper executable will be developed to support command-line interaction with the DLL. This software architecture will allow the main model (DLL) to be called directly from other third-party applications if desired; e.g., Microsoft Excel and Access, R, and other custom software graphical user interfaces. To demonstrate the implications of the developed modifiers, various management regimes would be projected with and without the modifiers and compared to long-term experimental locations like Austin Pond. The schedule for these deliverables is:

- Completion of plot database (6/2013)
- Preliminary analysis of model performance (9/2013)
- Development of equation modifiers (6/2014)
- Tests of long-term simulations (9/2014)
- Projections of long-term influence of various forest management regimes (5/2015)
- Enhanced Acadian-FVS model released (6/2015)

Potential Impacts of Alternative Future Land Uses on Forest Management and Wood Supply across Maine

photo Pamela Wells

Lead Principal Investigator

Spencer R. Meyer, Associate Scientist for Forest Stewardship, Center for Research on Sustainable Forests; and PhD Student, School of Forest Resources, University of Maine. Phone: 207.581.2872, Fax: 207.581.9358, Email: spencer.meyer@maine.edu.

Co-Principal Investigators

Michelle L. Johnson, Research Associate, Ecology and Environmental Science Program, University of Maine. Phone: 207.852.1181, Email: michelle.l.johnson@maine.edu.

Aaron Weiskittel, Assistant Professor of Forest Biometrics and Modeling, School of Forest Resources, University of Maine. Phone: 207.581.2857, Email: aaron.weiskittel@maine.edu.

Robert J. Lilieholm, E.L. Giddings Associate Professor of Forest Policy, School of Forest Resources, University of Maine. Phone: 207.581.2896, Email: roblilieholm@gmail.com.

Jeremy Wilson, Associate Professor of Forest Management, School of Forest Resources, University of Maine. Phone: 207.581.9213, Email: jeremy.wilson@maine.edu.

Christopher S. Cronan, Professor of Biology and Ecology, School of Biology and Ecology, University of Maine. Phone: 207.581.3235, Email: chris.cronan@umit.maine.edu.

Susan Stein, Private Forest Lands Studies Coordinator, USDA Forest Service. Phone: 202.205.0837, Email: sstein@fs.fed.us.

Overview

Maine is the most heavily forested state in the United States and has the highest percentage of its forests in private ownership (95%). These forests support rural economies across the state through forest-based manufacturing as well as outdoor recreation and tourism. However, much of Maine has a rural character, attractive quality-of-place, and relatively low land cost that continues to encourage development, which in turn puts pressure on private forest resources. The likely prospect of future development poses a risk to the wood supply upon which Maine's forest products economy relies. In this project, we are using a mixed-methods approach that combines land use planning with wood supply modeling to evaluate the potential impact of development on the forest products sector.

Goals and Objectives

Our specific objectives are to:

1. Create spatial maps of future development;
2. Summarize current development impact on forests;
3. Project future forest cover and volume; and
4. Evaluate trends and spatial patterns of impacts of future development on forests.

In November, 2012 we convened a group of stakeholders representing the economic development and forestry sectors. We used this group to refine and validate the land use models developed for two study watersheds in Maine. The final land use models from that process are presented in Figure 22. We also identified plausible future scenarios based on stakeholder input.

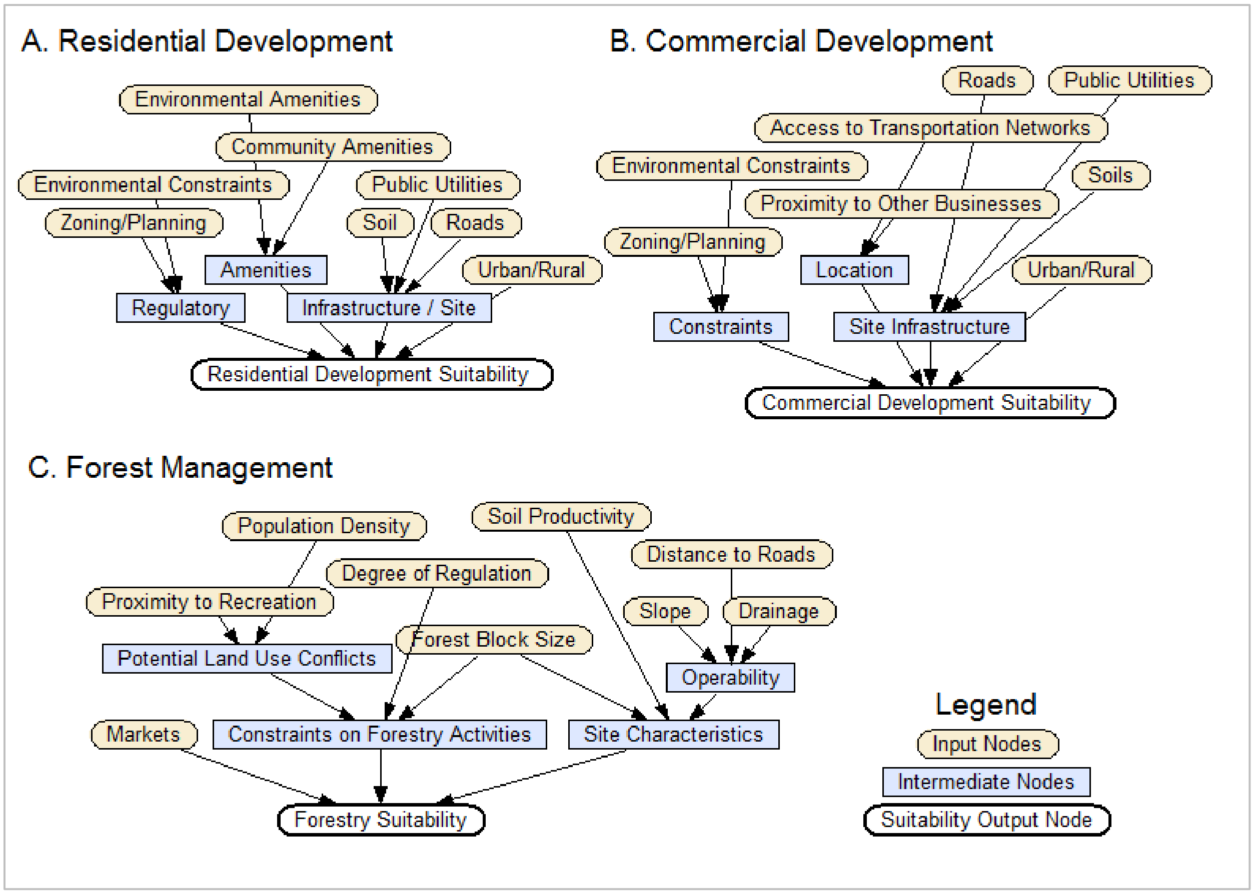


Figure 22. Land use suitability models developed jointly by stakeholders and researchers.

We have now completed the suitability mapping for both watersheds (Figure 23) and identified areas of potential conflict between the two. We have completed our future scenario modeling framework and are currently working on the linkage between forest inventory data and our spatial suitability and scenario maps. We have changed our approach for this objective. Rather than attempt to project forest inventory samples using FVS, as proposed, we will use the retrospective and future modeling of landowner harvesting behavior developed by Aaron Weiskittel, Erin Simons, and Kasey Legaard. We anticipate completing the cross-walk between the land use and forest productivity modeling during 2013/14. We plan to request an NSRC no-cost extension at the end of Year 2 (July 2014) to complete the final analyses (Objective 4) during FY 2014-15.

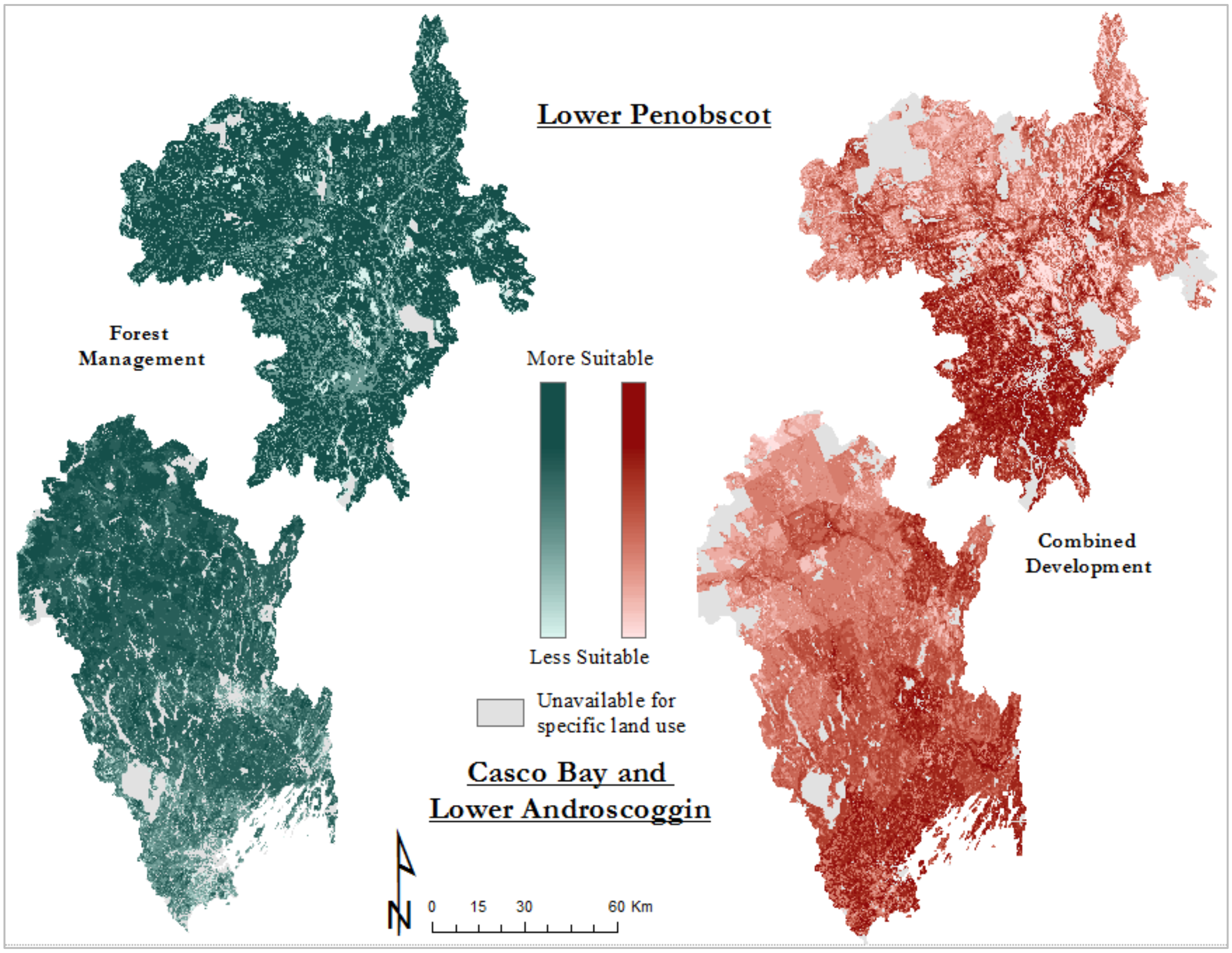


Figure 23. Complete land use suitability maps for two study watersheds. These models will be used as a basic for the future impact scenarios in the final phase of this project.

Updated Project Timeline

Objective	Proposed Completion	Updated Proposed Completion
Host focus group	December, 2012	Completed
Create spatial development maps	February, 2013	Completed
Summarize current impacts on forest	June, 2013	Completed
Project future forest	July, 2013	Anticipated February 2014
Assess spatial trends	December, 2013	Anticipated June 2014
Final report	June, 2014	Anticipated Fall 2014

Appendices

2012-2013 Publications and Presentations

Journal Publications (32)

Bataineh, M.M.., Wagner, R.G.. Weiskittel, A.R. 2013 Long-term response of spruce-fir stands to herbicide and precommercial thinning: observed and projected growth, yield, and financial returns in central Maine, USA. Canadian Journal of Forest Research. 43(4):385-395.

Bell, K.P., Lindenfeld, L., Speers, A,E., Teisl, M.F, Leahy, J.E. 2013. Creating opportunities for improving lake-focused stakeholder engagement: knowledge-action systems, pro-environment behavior and sustainable lake management. Lakes and Reservoirs: Research and Management 18 15-14.

Berven, K., Kenefic, L.S., Weiskittel, A.R., Twery, M., Wilson, J. 2013. The lost research of early northeastern spruce-fir experimental forests: a tale of lost opportunities. In: Long-Term Silvicultural and Ecological Studies, Volume 2. Edited by: Camp, A, Irland, L., Carroll, C. Yale University, Global Institute of Sustainable Forestry: 103-115.

Crista L. 2012. Improving Family Forest Knowledge Transfer through Social Network Analysis. Applied Environmental Education and Communication 11:157-164.

Dean, T., S. Roberts, and R. S. Seymour. (*in press*) Toward developing a direct relation between gross volume increment and stand density. Canadian Journal of Forest Research.

DeRose, R.J. and R.S. Seymour. 2012. Leaf area and structural changes after thinning in even-aged *Picea rubens-Abies balsamea* stands in Maine, USA. Internat. J. For. Research Volume 2012, Article ID 181057, doi:10.1155/2012/181057.

Gomben, P.C., R.J. Lilieholm, and M. Gonzalez-Guillen. 2012. Impact of Demographic Trends on Future Development Patterns and the Loss of Open Space in the California Mojave Desert. Environmental Management 49(2):305-324.

Gorczyca, E.L., Lyons, P.W., Leahy, J.E., Johnson, T.R., Straub C., Thornton, T., Leahy, J. 2012. Trust in Citizen Science Research: A Case Study of the Groundwater Education Through Water Evaluation and Testing Program. Journal of the American Water Resources Association 48:5 1032–1040

Guiterman, C. H., R. S. Seymour, and A.W. Weiskittel. 2012. Long-term thinning effects on the leaf area of *Pinus strobus* L. as estimated from litterfall and individual-tree allometric models. Forest Science 58:85-93.

Hiesl, P. and J.G. Benjamin. 2013. A Multi-Stem Feller-Buncher Cycle Time Model for Partial Harvests in Small Diameter Wood Stands. International Journal of Forest Engineering 24(2): 101-108.

Jansujwicz, J., A.J.K. Calhoun, J.E. Leahy, and R.J. Lilieholm. 2013. Using Framing Theory with Mixed Methods to Develop a Private Landowner Typology. Society and Natural Resources. 28(8): 945-961.

Jansujwicz, J.S., A.J.K. Calhoun, and R. Lilieholm. 2013. Using citizen science education and outreach to engage municipal officials and private landowners in vernal pool conservation. Environmental Management 52(6): 1369-1385.

Li, R., A. Weiskittel, A. Dick, J. A. Kershaw, Jr. and R. S. Seymour. 2012. Regional stem taper equations for eleven conifer species in the Acadian region of North America: Development and assessment. North. J. Appl. Forestry 29:5-14.

Lilieholm, R.J., S.R. Meyer, M.L. Johnson, and C.S. Cronan. 2013. Land Conservation in the Northeastern United States: An Assessment of Historic Trends and Current Conditions. Environment (in press).

Nelson, A.S., Saunders, M.R., Wagner, R.G., and A.R. Weiskittel. 2012. Early stand production of hybrid poplar and white spruce in mixed and monospecific plantations in eastern Maine. New Forests 43:519–534.

Nelson, A.S., Wagner, R.G., Saunders, M.R., and Weiskittel, A.R. 2013. Influence of management intensity on the productivity of early successional Acadian stands in eastern Maine. Forestry 86(1): 79-89.

Neupane, B., A. Halog, and R.J. Lilieholm. 2012. Environmental sustainability of wood-derived ethanol: A life cycle evaluation of resource intensity and emissions in Maine, USA. *Journal of Cleaner Production* 44:77-84.*

Olson, M.G. and R.G. Wagner. 2012. Forty years of spruce-fir stand development following herbicide application and precommercial thinning in northern Maine, USA. *Canadian Journal of Forest Research* 42:(1) 1-11.

Ranco, D., A. Arnett, E. Latty, A. Remsburg, K. Dunckel, E. Quigley, R. Lilieholm, J. Daigle, B. Livingston, J. Neptune, T. Secord. 2012. Two Maine Forest Pests: A Comparison of Approaches to Understanding Threats to Hemlock and Ash Trees in Maine. Maine Policy Review 21(1):76-89.

Rijal, B., Weiskittel, A.R., and J.A. Kershaw. 2012. Development of regional height to diameter equations for fifteen tree species in the North American Acadian Region. Forestry 85(3): 379-390.

Rijal, B., Weiskittel, A.R., Kershaw Jr, J.A., 2012. Development of height to crown base models for thirteen tree species of the North American Acadian Region. Forestry Chronicle 88, 60-73.

Roxby, G. and T. Howard. 2013. Whole-tree harvesting and site productivity: twenty-nine northern hardwood sites in central New Hampshire and western Maine. Forest Ecology and Management 293:114-121.

Saielli, T.M., Schaberg, P.G., Hawley, G.J., Halman, J.M., Gurney, K.M. 2012. Nut cold hardiness as a factor influencing the restoration of American chestnut in the northeastern United States. Canadian Journal of Forest Research, 42:849-857.

Schaberg, P.G., Saielli, T.M., Hawley, G.J., Halman, J.M., Gurney, K.M. In press. Growth and shoot winter injury of American chestnut seedlings grown in common garden at the species' northern range limit. Accepted with minor revision for inclusion in a NRS-GTR associated with the Central Hardwood Forest Conference, March 26-28, 2012, Morgantown, WV.

Sharik, T.L., and R.J. Lilieholm. 2012. A National Perspective on Forestry Education. Western Forester 57(2):1-5.

Simons-Legaard, E.M., Harrison, D.J., Krohn, W.B., J.H. Vashon. 2013. Canada lynx occurrence and forest management in the Acadian forest. The Journal of Wildlife Management. 77(3):567–578.

Smith, J.W., Anderson, D.H., Davenport, M.A., Leahy, J.E. 2013. Community benefits from managed resource areas: An analysis of construct Validity. Journal of Leisure Research 45(2).

Smith, J.W., Leahy, J.E, Anderson, D.H., Davenport, M.A. 2013. Community/Agency Trust: A Measurement Instrument Society and Natural Resources 26: 4472-477.

Snell, M., Bell, K.P., Leahy, J. 2013. Local institutions and lake management Lakes and Reservoirs: Research and Management. 18: 135-44.

Swift, D.E., D.H. Kiernan, E. Bevilacqua, and R.D. Nyland. 2012. Predicting future diameter of sugar maple in uneven-aged stands of west-central New Brunswick and New York. Forestry Chronincle. 88(4):420-425.

Thornton, T., Leahy, J. 2012. Changes in Social Capital and Networks: A Study of Community-Based Environmental Management Through a School- Centered Research Program Journal of Science Education and Technology 211 167-182.

Waskiewicz, J.,L.Kenefic, A. Weiskittel, and R. S. Seymour. 2013. Species mixture effects in northern red oak - eastern white pine stands in Maine, USA. Forest Ecology and Management. 298:71-81.

Books, Book Chapters and Editorships (4)

Kenefic, L.S., Brissette, J.C., Judd, R. In press. Northern conifer research: multiple species and multiple values. In: Research for the long-term: the interplay of societal need and research on USDA Forest Service Experimental Forests and Ranges. Edited by: R. Crawford, D. Hayes, and S. Stout. Springer.

Kenefic, L.S., Kern, C.C., Brissette, J.C., Weiskittel, A.R., Russell, M., Berven, K. 2013. Suggestions for maintaining records for long-term field studies. In: Long-Term Silvicultural and Ecological Studies, Volume 2. Edited by: Camp, A, Irland, L., Carroll, C. Yale University, Global Institute of Sustainable Forestry: 126-134.

Lilieholm R.J., C.S. Cronan, M. Johnson, S. Meyer, and D. Owen. 2013. Alternative Futures Modeling in Maine's Penobscot River Watershed: Forging a Regional Identity for River Restoration. Lincoln Institute of Land Policy, Cambridge, MA.

Meyer, S.R. (Ed.) 2012. Center for Research on Sustainable Forests Annual Report – 2011. University of Maine. Orono, Maine. 107 p.

Meyer, S.R., M.L. Johnson, and R.J. Lilieholm. 2012. Landscape Conservation in the United States: Evolution and Innovation across the Urban-Rural Interface. Pages 225- 258 (Chapter 13) in W. Zipper, D.N. Laband, and B.G. Lockaby, eds., Urban-Rural Interfaces: Linking People and Nature. Jointly published by the American Society of Agronomy, Crop Science Society of America, Soil Science Society of America. 332 pages.

Research Reports (21)

Benjamin, J.G. 2013. Biomass Utilization and Cost from Early Thinnings: CTL and Whole-Tree. Forest Resources Association – Technical Release. TR-13-R-4. February 2013. 3p.

Benjamin, J.G. and P. Hiesl. 2012. Harvesting Equipment Productivity Study 2012: Summary for Whole-Tree Systems and Cut-to-Length Systems in Maine. University of Maine, Cooperative Forestry Research Unit. 8p.

Benjamin, J.G., R. Seymour and J. Wilson. 2012. Early Commercial Thinning in Maine's Spruce-Fir Forests. Final Report for Cooperative Forestry Research Unit. December 2012. 6p.

Foertsch, I., J.E. Leahy, J.S. Wilson, and R.J. Lilieholm. 2012. Maine's Landowner Survey: Technical Report. Center for Research on Sustainable Forests, University of Maine. 104 pages.

Hiesl, P. and J.G. Benjamin. 2012. Machine Productivity and Cost: 2012 Update. Interim Report to Cooperative Forestry Research Unit. December 2012. 10p.

Johnson, M.L., S.R. Meyer, R.J. Lilieholm, and C.S. Cronan. Co-developing Place-based Scenarios of Alternative Futures with Stakeholders. 2012. Abstract in Proceedings of the American Association of Geographers Annual Meeting, New York, NY.

Krannich, R.S., J.W. Unger, III, and R.J. Lilieholm. 2013. 2011 Attitudinal Survey of Utah Anglers: Project Summary Report. Report submitted to the Utah Division of Wildlife Resources. Logan, Utah: Institute for Social Science Research on Natural Resources and Center for Society, Economy and the Environment, Utah State University. 228 pages.

Krannich, R.S., R.J. Lilieholm, and J. Unger. 2012. 2011-2012 Utah Angler Report: Project Summary Report. Utah Division of Wildlife Resources, Salt Lake City, Utah. 158 pages.

Lilieholm, R.J., C.S. Cronan, S. Meyer, and M. Johnson. 2012. Alternative Futures Modeling in the Lower Penobscot River Watershed, Maine. Working Paper. Lincoln Institute of Land Policy, Cambridge, MA.

Nelson, A.S., Wagner, R.G., Weiskittel, A.R. 2012. Verification of regional and national aboveground sapling biomass equations in Maine. *In* Cooperative Forestry Research Unit 2012 Annual Report. *Edited by* B. Roth, Orono, ME.

Nelson, A.S., Weiskittel, A.R., Wagner, R.G., and Saunders, M.R. 2012. Verification of the Jenkins and FIA Sapling biomass equations for hardwood species in Maine. *In* Moving from Status to Trends: Forest Inventory and Analysis (FIA) Symposium 2012. *Edited by* R.S. Morin, and G.C. Liknes. USDA Northern Research Station Gen. Tech. Rep. NRS-P-105, Baltimore, MD. pp. 373-377.

Nelson, A., and R. Wagner. 2012. Influence of silvicultural intensity and species composition on the productivity of early successional stands in Maine. pp. 24-28, *In* Roth, B. (Ed.) Cooperative Forestry Research Unit: 2011 Annual Report. University of Maine, Orono, ME. 110p.

Olson, M., S. Meyer, R. Wagner, and R. Seymour. *In press.* Response of tree regeneration to commercial thinning in spruce-fir forests of Maine: First-decade results from the Commercial Thinning Research Network. In: Cooperative Forestry Research Unit: 2012 Annual Report, B. Roth (Ed.). University of Maine, Orono.

Olson, M., S. Meyer, R. Wagner, and R. Seymour. 2012. Response of Tree Regeneration to Commercial Thinning In Spruce-Fir Stands of Maine: First Decade Results From the Commercial Thinning Research Network. pp. 20-23, *In* Roth, B. (Ed.) 2012. Cooperative Forestry Research Unit: 2011 Annual Report. University of Maine, Orono, ME. 110p.

Pekol, J., A. Weiskittel, R. Seymour, and R. Wagner. 2012. Influence of Commercial Thinning on Stand and Tree-Level Mortality Patterns of Balsam Fir and Red Spruce Forests in Maine With and Without Precommercial Thinning. pp. 56-65, *In* Roth, B. (Ed.) 2012. Cooperative Forestry Research Unit: 2011 Annual Report. University of Maine, Orono, ME. 110p.

Ranco, D., J. Daigle, R.J. Lilieholm, J. Neptune, and T. Secord. 2012. Protecting Ash for Future Generations III: Symposium Report. Sustainability Solutions Initiative, University of Maine. 22 pages.

Roth, B., R. Wagner, R. Seymour, A. Weiskittel, and S. Meyer. 2012. Commercial Thinning Research Network: 2011 Update. pp. 18-19, *In* Roth, B. (Ed.) 2012. Cooperative Forestry Research Unit: 2011 Annual Report. University of Maine, Orono, ME. 110p.

Wagner, R. 2012. Director's Report. pp. 6, *In* Roth, B. (Ed.) Cooperative Forestry Research Unit: 2011 Annual Report. University of Maine, Orono, ME. 110p.

Wagner, R. and A. Weiskittel. 2012. Center For Advanced Forestry Systems (CAFS). pp. 16, *In* Roth, B. (Ed.) Cooperative Forestry Research Unit: 2011 Annual Report. University of Maine, Orono, ME. 110p.

Weiskittel, A., B. Rice, J. Wilson, and R. Wagner. 2012. Improved Sampling Methods and Growth and Yield Models for Partially Harvested Stands. pp. 37-39, *In* Roth, B. (Ed.) 2012. Cooperative Forestry Research Unit: 2011 Annual Report. University of Maine, Orono, ME. 110p.

Weiskittel, A., M. Russell, R. Wagner, and R. Seymour. 2012. Refinement of the Forest Vegetation Simulator Northeast Variant Growth and Yield Model: Phase III. pp. 85-93, *In* Roth, B. (Ed.) 2012. Cooperative Forestry Research Unit: 2011 Annual Report. University of Maine, Orono, ME. 110p.

Theses (7)

Bland, A. 2012. Age and density patterns in leaf area index and growth efficiency of eastern white pine stands in Maine. MS Thesis. University of Maine, Orono, ME.

Clune, P. 2013. Growth and Development of Maine Spruce-fir Forests Following Commercial Thinning. MS Thesis. University of Maine, Orono, ME.

Hiesl, P. 2013. Productivity Standards for Whole-Tree and Cut-to-Length Harvesting Systems in Maine. MS Thesis, University of Maine. 166p.

Looze, B. 2012. Analysis of fragmentation and prediction of large diameter forest in Maine, MS Thesis. University of Maine, Orono.

Nystrom, L. 2012. *Modeling Ingrowth in Northern Hardwood Selection System Stands*. MS Thesis. SUNY Coll. Environ. Sci. and For., Syracuse, NY.

Russell, M.B. 2012. Modeling individual tree and snag dynamics in the mixed-species Acadian forest. PhD Dissertation. University of Maine. Orono, ME.

Sypitkowski, E. 2012. Abundance, composition, and size of the regeneration on the Penobscot Experimental Forest and the Acadian Forest Ecosystem Research Project in central Maine. MF Report, University of Maine, Orono, ME.

Proceedings, Presentations , Posters, Field Tours and Workshops (130)

Bataineh, M., Kenefic, L., Weiskittel, A., Wagner, R., Brissette, J., and Seymour, R. 2012. An overview of the project "Evaluating and predicting the regional effects of silviculture and site factors on regeneration in the Northern Conifer Forest". The Penobscot Experimental Forest, Maine, June 14, 2012. – Field Tour

Bataineh, M., A. Nelson, R. Wagner, B. Roth, and A. Weiskittel. 2013. Individual-tree response to commercial thinning in northern Maine: Influence of including competition, site, and treatment regime in growth and yield models. Center for Advanced Forestry Systems (CAFS) Annual Meeting, April 9-11, 2013, St. Simmons, GA.

Bataineh, M.M., L. Kenefic, A.R.Weiskittel, R.G. Wagner, J. Brissette, and R.S. Seymour. 2012. The relative importance of harvesting and local site factors in structuring regeneration abundance and composition in partially harvested stands in central Maine. Eastern CANUSA Forest Science Conference, Durham, New Hampshire, November 2-3, 2012.

Bataineh, M.M., R.G. Wagner, and A.R. Weiskittel. 2012. Capturing value through thinning - Forty-year results from the Austin Pond study. Cooperative Forestry Research Unit Forester's Workshop, May 16, 2012, Orono, ME.

Benjamin, J.G., Meacham, E., R. Seymour and J. Wilson. 2012. Early Commercial Thinning in Maine's Spruce-Fir Forests. Paper presented at the 35th Council on Forest Engineering: *Engineering New Solutions for Energy Supply and Demand.* New Bern, NC. September 9-12, 2012.

Benjamin, J.G. 2013. iFOR – The University of Maine's Innovative Forest Operations Research Program. Northern Hardwood Research Institute Seminar Series. Edmundston, NB. April 10.

Benjamin, J.G. 2012. Biomass Retention on Whole-Tree Harvesting Operations. NHTOA and UNH Cooperative Extension: Biomass Harvesting – What Gets Left Behind? Bristol, NH. July 26.

Benjamin, J.G. 2013. Effect of Stem Size on Harvesting Costs from Early Commercial Thinnings. Association of Consulting Foresters Meeting. Brewer, ME. April 25.

Benjamin, J.G. 2013. Forest Business Planning Workshop – NE Logging Industry Overview and Process Improvement. Vermont Forest Parks and Recreation Department. Essex Junction, VT. May 10.

Benjamin, J.G. 2013. The University of Maine's iFOR Program: Innovative Forest Operations Research. Northeastern Loggers' Association Equipment Expo and Logger Workshops. Bangor, ME. May 17.

Benjamin, J.G. 2013. What is the Value of Your Time? Productivity Improvement Workshop for Treeline Inc. Lincoln, ME. May 3.

Benjamin, J.G. and P. Hiesl. 2013. Influence of Stem Size and Cycle Time on Harvest Cost. New England Council on Forest Engineering Annual Meeting. *Legal Issues in Forestry and Foresters…..Knowing Your Costs.* University of Maine, Orono, ME. March 11-12, 2013.

Benjamin, J.G. and P. Hiesl. 2012. Harvesting equipment productivity study update. Presented at the CFRU Fall Advisory Committee meeting, October 17th. Orono, ME.

Benjamin, J.G., R. S. Seymour, E. Meecham, and J. Wilson. (*in review*) Impact of whole-tree and cut-to-length harvesting on post-harvest condition and logging costs for early commercial thinning in Maine. N. Jour. Appl. For. *(in review)*

Bick, S. and J.G. Benjamin. 2013. Exploring Woody Biomass Harvesting Guidelines. NYSAF – NESAF Joint Annual Meeting. Common Ground Found? Revisiting the Findings and Recommendations of the Northern Forest Land Council. Saratoga, NY. January 29 – February 1, 2013.

Brockmann, D. and P. Hiesl. 2013. Austin Pond Study: Silvicultural and operational harvesting update. Presented at the CFRU Winter Advisory Committee meeting, January 23rd. Orono, ME.

Clune, P., R. Wagner, A. Weiskittel, and R. Seymour. 2013. Growth and development of Maine spruce-fir stands following commercial thinning. Center for Advanced Forestry Systems (CAFS) Annual Meeting, April 9-11, 2013, St. Simmons, GA.

Clune, P., R. Wagner, R. Seymour, A. Weiskittel. 2012. Growth and Development of Maine Spruce-fir Forests Following Commercial Thinning. Poster presented at National Science Foundation, Center for Advanced Forestry Systems (CAFS) 2012 Annual Meeting, June 26-28, 2012, Bangor, ME.

Clune, P. 2013. Growth and development of Maine spruce-fir stands following commercial thinning. Presented at the CFRU Winter Advisory Committee meeting, January 23rd. Orono, ME.

Dean, T., S. Roberts, and R. S. Seymour. (*in press*) Toward developing a direct relation between gross volume increment and stand density. Can. J. For. Res.

DeRose, R.J. and R.S. Seymour. 2012. Leaf area and structural changes after thinning in even-aged *Picea rubens-Abies balsamea* stands in Maine, USA. Internat. J. For. Research Volume 2012, Article ID 181057, doi:10.1155/2012/181057.

Guiterman, C. H., R. S. Seymour, and A.W. Weiskittel. 2012. Long-term thinning effects on the leaf area of *Pinus strobus* L. as estimated from litterfall and individual-tree allometric models. Forest Science 58:85-93.

Hennigar, C.R. and A.R. Weiskittel. 2012. FVS growth model: Acadian variant update. Presented at the CFRU Fall Advisory Committee meeting, October 17th. Orono, ME.

Hennigar, C.R., MacLean, D.A., Erdle, T.A. Amos-Binks, L. and T. Brown. 2012. Potential spruce budworm impacts and mitigation opportunities in Maine. Presented at the CFRU Fall Advisory Committee meeting, October 17th. Orono, ME.

Hiesl, P. and J.G. Benjamin. 2012. Cycle Time Analysis of an Early Commercial Thinning Treatment Study in Maine. Paper presented at the 35th Council on Forest Engineering: *Engineering New Solutions for Energy Supply and Demand.* New Bern, NC. September 9-12, 2012.

Johnson, M.L. 03/13 Stakeholder Engagement in Future Land Use Scenarios. Conference on Students as Catalysts for Large Landscape Conservation. Colby College, Waterville, ME. (with Meyer, Lilieholm and Cronan).

Johnson, M.L. 04/13 Lessons Learned from Evaluating Co-produced Spatial Models of Land Use Suitability in Central Maine. AAAS SSI Review, UMaine (with Lilieholm, Meyer, Cronan, Tremblay, Gallandt, and Wilson).

Johnson, M.L., S.R. Meyer, R.J. Lilieholm, and C.S. Cronan. 11/12 Developing a Replicable, Stakeholder-engaged Qualitative-Quantitative Landscape Scenario Process. American Association of Collegiate Schools of Planning, Cincinnati.

Johnson, M.L., S.R. Meyer, R.J. Lilieholm, C.S. Cronan, Tremblay, Gallandt, and Wilson. 05/13 Lessons Learned from Evaluating Co-produced Spatial Models of Land Use Suitability in Central Maine. SSI Retreat, SERC

Kenefic, L.S. and *Weiskittel, A.R*. 2013. U.S. Forest Service Research in Northern Conifers:
Historical Perspective, Management Implications, and Modeling Applications. Invited webinar. Northeastern States Research Cooperative. March 21.

Leahy, J. and Merk, R. Lessons Learned: Legacy Planning for Forest Landowners. May 2013. Maine Land Conservation Conference, Topsham, ME.

Leahy, J. and Straub, C. Whose Woods?: Adventures in Human dimensions Research at UMaine. Presentation. May 2013 Belgrade Lakes Research Center, Belgrade Lakes, ME.

Leahy, J. and Townsend, B. The Theory of capitals applied to limited resource landowners in Maine. October 2013. Society of American Foresters National Convention. October 2012. Spokane, WA.

Leahy, J., Straub, C.,Quartuch, M., Bell, K., Colby-George, J., Vanderlugt, B., Daigle, J. and Weiskittel, A. Examining the Lack of Succession Planning among Family Forest Landowners in Kennebec County, Maine. October 2013. International Union of Forest Research Organizations Small Scale Forestry Working Group Meeting. Amherst, MA.

Legaard, K.R., S. Sader, J. Wilson, E. Simons-Legaard, and A. Weiskittel. 2013. A spatial assessment of vulnerability to defoliation by spruce budworm across the commercial forestland of northern Maine. New England Society of American Foresters Spring Meeting, Bethel, Maine.

Legaard, K.R., S. Sader, J. Wilson, E. Simons-Legaard, and A. Weiskittel. 2012. Mapping vulnerability to defoliation by spruce budworm using Landsat satellite imagery and FIA field plots. Eastern CANUSA Forest Science Conference, Durham, New Hampshire.

Li, R., A. Weiskittel, A. Dick, J. A. Kershaw, Jr. and R. S. Seymour. 2012. Regional stem taper equations for eleven conifer species in the Acadian region of North America: Development and assessment. North. J. Appl. Forestry 29:5-14.

Lilieholm R.J. 06/12 Alternative Futures Modeling: Understanding the Past, Envisioning the Future. Convergence 2012, College of the Atlantic, Bar Harbor, ME.

Lilieholm R.J. 12/12 The Acadian Internship in Large Landscape Conservation. School of Forest Resources Seminar Series. University of Maine.

Lilieholm R.J., C.S. Cronan, M. Johnson, S. Meyer . 02/13 Alternative Futures Modeling in Maine: Understanding the Past... Envisioning the Future. Belfast Bay Watershed Coalition, Belfast Public Library.

Lilieholm R.J., C.S. Cronan, M. Johnson, S. Meyer . 03/13 Alternative Futures Modeling in Maine. Students as Catalysts for Large Landscape Conservation, Colby College, Waterville.

Lilieholm, R.J. 04/13 Alternative Futures Modeling in Kenya's National Parks and Reserves. AAAS SSI Review, UMaine (with Sader, Boone, Reid, Said, Worden, Kifugo, Nkedianye and Stabach).

Lilieholm, R.J. 10/12 Kibale Forest Wild Coffee: Market-based Incentives for Community Collaboration and Conservation in Africa. SFR 226 Park Systems of the World. University of Maine, School of Forest Resources (Deurioste-Stone, Instructor).

Lilieholm, R.J. 11/12 Alternative Futures Modeling in Kenya's National Parks. SFR 226 Park Systems of the World. University of Maine, School of Forest Resources (Deurioste-Stone, Instructor).

Lilieholm, R.J. 03/12 Alternative Futures Modeling in Kenya's National Parks and Reserves. Conference on Students as Catalysts for Large Landscape Conservation. Colby College, Waterville, ME. (with Sader, Boone, Reid, Said, Worden, Kifugo, Nkedianye and Stabach).

Lilieholm, R.J. 03/13 Acadian Internship in Regional Conservation and Stewardship. Conference on Students as Catalysts for Large Landscape Conservation. Colby College, Waterville, ME. (with Slotten, Mahung, Levitt and Davis).

Lilieholm, R.J. 03/13 Alternative Futures Modeling in Maine and East Africa. Landscape Ecology and Modeling Laboratory, Global Institute of Sustainability, Arizona State University.

Lilieholm, R.J. 03/13 Engaging High School Students in Science-based Study Abroad Programs: Leatherback Sea Turtle Research and Conservation at the Pacuare National Reserve, Costa Rica. Conference on Students as Catalysts for Large Landscape Conservation. Colby College, Waterville, ME. (Morris).

Lilieholm, R.J. 04/13 Acadian Internship in Regional Conservation and Stewardship. AAAS SSI Review, UMaine (with Slotten, Mahung, Levitt and Davis).

Lilieholm, R.J. 06/13 Alternative Futures Modeling in Maine and Africa. Hampden Academy (Kathryn King, Instructor), Hampden, Maine.

Lilieholm, R.J. 06/13 Alternative Futures Modeling in Maine. Presentation to Upward Bound students, EPSCoR, UMaine.

Lilieholm, R.J. 09/12 Alternative Futures Modeling in Maine and Africa. Colby College class on Landscape Conservation (Phillip Nyhus, Instructor). University of Maine, Mitchell Center.

Lilieholm, R.J. 09/12 Introduction to Forest Management and Economics. SFR 103. University of Maine, School of Forest Resources (Wagner, Instructor).

Lilieholm, R.J. 09/12 Introduction to Forest Management. Guest lectures in SFR 477 (2 hours). University of Maine, School of Forest Resources (Livingston, Instructor).

Lilieholm, R.J. 09/12 The Acadian Internship in Regional Conservation and Stewardship. Acadia National Park Science Symposium, Schoodic Education and Research Center, Winter Harbor, Maine (Davis presenting, with Lilieholm and Levitt).

Lilieholm, R.J. 11/12 Timber Harvest Scheduling. Guest lectures in SFR 477 (8 hours). University of Maine, School of Forest Resources (Livingston, Instructor).

Lilieholm, R.J., Slotten, Mahung, Levitt and Daivs. 05/13 Acadian Internship in Regional Conservation and Stewardship. SSI Retreat, SERC

Lilieholm, R.J., J.F. Lilieholm and Morris . 04/13 Engaging High School Students in Science-based Study Abroad Programs: Leatherback Sea Turtle Research and Conservation at the Pacuare National Reserve, Costa Rica. AAAS SSI Review, UMaine.

Lilieholm, R.J., J.F. Lilieholm and Morris . 05/13 Engaging High School Students in Science-based Study Abroad Programs: Leatherback Sea Turtle Research and Conservation at the Pacuare National Reserve, Costa Rica. SSI Retreat, SERC.

Lilieholm, R.J., Sader, Boone, Reid, Said, Worden, Kifugo, Nkedianye and Stabach. 05/13 Alternative Futures Modeling in Kenya's National Parks and Reserves. SSI Retreat, SERC.

Lilieholm, Robert. 05/13 Discussant – Universities as Catalysts for Large Landscape Conservation. Lincoln Institute of Land Policy, Cambridge, MA

Lilieholm, Robert. Invited Participant. Strategic Planning Focus Group, Maine Coast Heritage Trust, Augusta, ME. September 2012.

Mann, M. and Leahy, J. Place Attachment and the Forested Landscape of the Kennebec Watershed, ECANUSA. November 2012. Durham, NH.

Meyer, S. (presenter), M. Olson, R. Wagner, and R. Seymour. "Response of softwood regeneration to commercial thinning in two northeastern spruce-fir stand types: 1st-decade results from the Commercial Thinning Research Network in Maine". 2012 Eastern CANUSA Forest Science Conference, University of New Hampshire, November 1-3, 2012.

Meyer, S., R.J. Lilieholm, C. Cronan, M. Johnson, Foster04/13 Historical Patterns and Drivers of Land Conservation in Northern New England: 1850-2010. U.S. International Association of Landscape Ecology. Austin, TX.

Meyer, S.R. 03/13 Identifying Opportunities for Watershed Protection and Regional Planning in a Mixed-Land Use Modeling Framework.. Conference on Students as Catalysts for Large Landscape Conservation. Colby College, Waterville, ME. (with Johnson, Lilieholm and Cronan).

Meyer, S.R. 03/13 Spatial and Temporal Distribution of Conserved Lands in Maine and the Northeast: A First Look. Conference on Students as Catalysts for Large Landscape Conservation. Colby College, Waterville, ME. (Meyer presenting, with Johnson, Lilieholm and Cronan).

Meyer, S.R., M.L. Johnson, R.J. Lilieholm, and C.S. Cronan. 2012. Using GIS to Support Maine's Sustainability Solutions Initiative. Panel Participant, Northeast Arc Users Group. Rockland, ME. November 13, 2012. (Invited)

Meyer, S.R., M.L. Johnson, R.J. Lilieholm, and C.S. Cronan. 2012. Of the People, By the People, and For the People: Stakeholder-Driven Alternative Futures Research across the Maine Landscape. Future Scenarios of Landscape Change: Tools and Tactics. Harvard Forest Conference and Webinar, Petersham, MA. August 17, 2012. (Invited)

Meyer, S.R. 04/13 Identifying Opportunities for Watershed Protection and Regional Planning in a Mixed-Land Use Modeling Framework.. AAAS SSI Review, UMaine (with Johnson, Lilieholm and Cronan).

Meyer, S.R., M.L. Johnson, R.J. Lilieholm, and C.S. Cronan. 05/13 Identifying Opportunities for Watershed Protection and Regional Planning in a Mixed-Land Use Modeling Framework. SSI Retreat, SERC.

Meyer, S.R. Maine's Sustainability Solutions Initiative: Of the People, by the People, and For the People [and Nature]. An invited presentation at the Maine Woods Forever Roundtable. Unity, ME. March 15, 2013.

Meyer, S.R. Past Performance Does Not Guarantee Future Results: Why we need strategic approaches to conservation design. Presentation to staff and board members of the Harris Center for Conservation Education. Hancock, NH. March 8, 2013.

Meyer, S.R. Spatial and Temporal Patterns of a Landscape Conservation Portfolio. University of Maine, School of Forest Resources Noon-time Seminar. Orono, ME December 14, 2012.

Meyer, S.R., M.L. Johnson, R.J. Lilieholm, C.S. Cronan, D. Owen, T. Parr, and S. Smith. 2012. Linking Development and Conservation Suitability Mapping with Watershed Risk. Presentation to the Maine Department of Environmental Protection. Augusta, ME. November 15, 2012.

Meyer, S.R., Olson, M.G., Wagner, R.G. and R.S. Seymour. 2012. Response of softwood regeneration to commercial thinning in two northeastern spruce-fir stand types. Presented at the CFRU Fall Advisory Committee meeting, October 17th. Orono, ME.

Nelson, A.S., A.R. Weiskittel, R.G. Wagner, and M.R. Saunders. 2012. Development and validation of aboveground sapling biomass equations in Maine. Northeastern Mensurationist Organization (NEMO) 2012 Meeting. October 1, 2012, State College, PA.

Nelson, A.S., R.G. Wagner, M.R. Saunders, and A.R. Weiskittel. 2012. Influence of Management Intensity on The Productivity of Early Successional Acadian Stands in Eastern Maine. Eastern CANUSA Forest Science Conference, Durham, New Hampshire, November 2-3, 2012.

Nelson, A.S., Weiskittel, A.R., Wagner, R.G., and Saunders, M.R. 2012. Vertical distribution and total tree leaf area equations of juvenile trees in eastern Maine. Southern Mensurationist 2012 Annual Meeting, October 7-9, 2012, Jacksonville, FL.

Nelson, A.S., Weiskittel, A.R., Wagner, R.G., and Saunders, M.R. 2012. Verification of the Jenkins and FIA Sapling biomass equations for hardwood species in Maine. In Moving from Status to Trends: Forest Inventory and Analysis (FIA) Symposium 2012. Edited by R.S. Morin, and G.C. Likens. USDA Northern Research Station Gen. Tech. Rep. NRS-P-105, Baltimore, MD. pp. 373-377.

Nelson, A.S., Wagner, R.G., Saunders, M.R., and Weiskittel, A.R. 2012. Influence of silvicultural intensity and species composition on the productivity of young Acadian stands in eastern Maine. *Presented at:* 2012 Eastern Canada-USA Forest Science Conference. Durham, NH

Nelson, A.S., Weiskittel, A.R., Wagner, R.G., and Saunders, M.R. 2012. Vertical distribution and total tree leaf area equations of juvenile trees in eastern Maine. *Presented at:* Southern Mensurationist 2012 Annual Meeting. Jacksonville, FL.

Nyland, R. American Beech: Menace of Northeastern Hardwood Forests. Presented at two workshop for Adirondack Chapter, NY Society of American Foresters, Newcomb, NY. 18 Aug 2012 and 20 Aug 2012.

Nyland, R. American Beech: Menace of Northeastern Hardwood Forests. Workshop presentation for Empire State Forest Products Association, Timber Harvesters Training Program. Newcomb, NY. 20 Nov. 2012.

Nyland, R. Regenerating Northern Hardwoods, a field tour for US Forest Service staff of White Mountain National Forest at Huntington Wildlife Forest, Newcomb, NY. August 2012

Olson, M., S. Meyer, R. Wagner, and R. Seymour. 2012. Response of Softwood Regeneration to Commercial Thinning in Two Northeastern Spruce-Fir Stand Types: 1st Decade Results From the Commercial Thinning Research Network in Maine. Eastern CANUSA Forest Science Conference, Durham, New Hampshire, November 2-3, 2012.

Pelletier, G. 2013. Introducing the new Northern Hardwoods Research Institute. Presented at the CFRU Winter Advisory Committee meeting, January 23rd. Orono, ME.

Puhlick, J.J., A.R. Weiskittel, I.J. Fernandez, R.S. Seymour, S. Fraver, and L. S. Kenefic. 2013. How silvicultural treatments and site quality affect carbon storage on the Penobscot Experimental Forest. North American Forest Ecology Workshop (oral presentation), Bloomington, IN, June 16-20, 2013.

Puhlick, J.J., A.R. Weiskittel, L. S. Kenefic, I.J. Fernandez, S. Fraver, L.E. Rustad, R.K. Kolka, and J.C. Brissette. 2012. How silvicultural treatments affect carbon storage on the Penobscot Experimental Forest: A 60-year perspective. Eastern CANUSA Forest Science Conference (oral presentation), Durham, NH, November 1-3, 2012.

Quartuch, M. R., Daigle, J., Leahy, J., and Bell, K. 2012. Stewardship versus development: Exploring landowner ethics and behavioral intentions. Society of American Foresters National Conference, October 24-28, 2012. Spokane, Washington (Oral-poster).

Quartuch, M. R., Daigle, J., Leahy, J., and Bell, K. 2013. Predicting development intentions of private family forest landowners in Maine through attitudes, norms, perceived control, and stewardship ethics. International Symposium on Society and Resource Management, June 4-8, 2013. Estes Park, CO (oral)

Quartuch, M. R., Daigle, J., Weiskittel, A., Vanderlugt, B., Straub, C., Leahy, J., Colby-George, J., and Bell, K. 2012. Using sense of place and sense of community to understand landscape change behaviors. Maine EPSCoR Conference, September 24, 2012. Orono, Maine (poster).

Rice B., A.R. Weiskittel, and R.G. Wagner. Horizontal line sampling- just interesting or is it feasible? Southern Mensurationists 2012 Meeting. Jacksonville, FL. October 9, 2012.

Rice B., R.G. Wagner and A.R. Weiskittel. Forest inventory methods in Maine's partially harvested stands. Northeastern Mensurationist Organization (NEMO) 2012 Meeting. State College, PA. October 1, 2012.

Rice B., R.G. Wagner and A.R. Weiskittel. Natural regeneration following partial harvesting in Maine, Society of American Foresters National Convention. Spokane, WA, October 25, 2012.

Rice B., A.R. Weiskittel and R.G. Wagner. In Review. Efficiency of alternative forest inventory methods in partially harvested stands. European Journal of Forest Research.

Rice, B., R.G. Wagner, and A.R, Weiskittel. 2012. Nonselective Partial Harvesting in Maine. Eastern CANUSA Forest Science Conference, Durham, New Hampshire, November 2-3, 2012.

Roth, B.E., Wagner, R.G., Seymour, R.S., Weiskittel, A.R. and S.R. Meyer. 2012. Commercial Thinning Research Network (CTRN) and Austin Pond project updates. Presented at the CFRU Fall Advisory Committee meeting, October 17th. Orono, ME.

Russell, M., A. Weiskittel, and R. Wagner. 2012. Refinement of Regional Growth and Yield Models for Naturally-Regenerated, Mixed Species Stands in the Northeast. National Science Foundation, Center for Advanced Forestry Systems (CAFS) 2012 Annual Meeting, June 26-28, 2012, Bangor, ME.

Schaberg, P.G., Murakami, P.F., Gurney, K.M., Saielli, T.M., Hawley G.J., Halman, J.M., Fitzsimmons, S.F. 2012. Exploring how genetics and silvicultural management influence the performance of American chestnut in the north. Poster presentation at the 2012 American Chestnut Summit, Asheville, NC. October 20, 2012.

Schaberg, P.G., Saielli, T.M., Hawley G.J., Halman, J.M., Gurney, K.M. 2012. Winter injury of American chestnut seedlings grown in a common garden at the species' northern range limit. Proceedings of the 18th Central Hardwood Forest Conference, West Virginia University, Morgantown, WV. March 27, 2012. p. 30 (Abstract).

Schaberg, P.G., Saielli, T.M., Hawley G.J., Halman, J.M., Gurney, K.M. 2012. Growth versus protection from the cold: a tradeoff for American chestnut grown at the species' northern range limit? Eastern CANUSA Forest Science Conference, The University of New Hampshire, Durham, NH, November 3, 2012.

Schmidt, D.A. American Beech: Menace of Northeastern Hardwood Forests. Presented at two workshop for Adirondack Chapter, NY Society of American Foresters, Newcomb, NY. 18 Aug 2012 and 20 Aug 2012.

Schmidt, D.A. American Beech: Menace of Northeastern Hardwood Forests. Workshop presentation for Empire State Forest Products Association, Timber Harvesters Training Program. Newcomb, NY. 20 Nov. 2012.

Schmidt, D.A. Modeling Growth and mortality of northern hardwoods in even-aged stands in New York. A presentation at the NY-NE Societies of American Foresters Joint Annual Meeting, Saratoga Springs, NY. 31 January 2013.

Schmidt, D.A. Modeling Growth and mortality of northern hardwoods in even-aged stands in New York. A seminar at SUNY Coll. Environ. Sci, and For., Syracuse, NY. 6 May 2013

Schmidt, D.A. Regenerating Northern Hardwoods, a field tour for US Forest Service staff of White Mountain National Forest at Huntington Wildlife Forest, Newcomb, NY. August 2012

Seymour, R. S. and M. S. Greenwood. 2013. Development of Weevil-Resistant Varieties of White Pine (*Pinus strobus L.)* Nutting Hall Noontime Seminar Series. Orono, ME.

Sharik, T.L., Lilieholm R.J., Richardson. 06/12 Trends in Higher Education related to Forestry and Natural Resource Management. Great Lakes Forest Industry, Products and Resources Summit, Keshena, WI.

Sharik, T.L., Lilieholm R.J., Richardson. 06/13 Undergraduate Forestry Enrollment Trends in the U.S. Conference on The Future of Diversity on Our Disciplines and Careers: Natural Resources and the Environment. Virginia Tech, June 19-21 (Keynote).

Simons-Legaard, E., K. Legaard, J. Wilson, A. Weiskittel, and S. Sader. 2012. Long-term outcomes and tradeoffs of forest policy and management practices on the broad-scale sustainability of forest resources: wood supply, carbon, and wildlife habitat. Eastern CANUSA Forest Science Conference, Durham, New Hampshire.

Sypitkowski, E. 2012. Regeneration in multi-aged partial harvests. Master of Forestry Seminar, University of Maine, December 16, 2012. – Presentation

Virgin, G. and D.A. MacLean. 2012. Long-term regeneration and succession at Green River, NB following the 1950's spruce budworm outbreak. Presented at the CFRU Fall Advisory Committee meeting, October 17th. Orono, ME.

Wagner, R.G. 2012. Commercial Thinning Research Network: 10-Year Growth and Mortality Patterns. CFRU Forester's Workshop, University of Maine, Orono, Maine.

Wagner, R.G. 2012. Improving the Composition of Beech-Dominated Northern Hardwood Understories in Northern Maine. Maine Society of American Foresters Fall Meeting, October 9, 2012, Orono, Maine.

Wagner, R.G. 2012. Improving the Composition of Beech-Dominated Northern Hardwood Understories in Northern Maine. Pesticide Recertification Meeting, Bangor, ME. (Apr 2012)

Wagner, R.G. 2012. Overview of CFRU Research. Plum Creek Annual Forester's Meeting, Greenville, ME. (May 2012)

Wagner, R.G. 2012. Overview of Northeast States Research Cooperative (NSRC). North East State Foresters Association Meeting Concord, NH. (May 2012)

Wagner, R.G. 2013. A Maine idea that revolutionized forestry research and graduate education in the US: The 50th anniversary of the McIntire-Stennis Cooperative Forestry Research Program (1962 – 2012). Presented at the CFRU Winter Advisory Committee meeting, January 23rd. Orono, ME.

Wagner, R.G. and Clune P. 2013. Growth and Development of Maine Spruce-fir Forests Following Commercial Thinning. Presented at the Center for Advanced Forestry Systems annual meeting. St. Simons Island, GA. April 9th - 11th., 2013

Wagner, R.G. and Roth, B.E. 2013. Overview of forestry in Maine and the Cooperative Forestry Research Unit. Presentation to the University of Applied Forest Sciences. Rottenburg, Germany. May 13th, 2013.

Wagner, R.G. and Roth, B.E. 2012. Overview of forestry in Maine and the Cooperative Forestry Research Unit. Presentation to the Swedish University of Agricultural Sciences. Alnarp, Sweden. May 13th, 2013.

Waskiewicz, J.,L.Kenefic, A. Weiskittel, and R. S. Seymour. 2013. Species mixture effects in northern red oak - eastern white pine stands in Maine, USA. Forest Ecol Manage. 298:71-81.

Weiskittel, A. and R. Wagner. 2013. Extending the Acadian Variant of the Forest Vegetation Simulator (FVS) to managed stands in the Northeast US. Center for Advanced Forestry Systems (CAFS) Annual Meeting, April 9-11, 2013, St. Simmons, GA.

Weiskittel, A., and R. Wagner. 2012. Extending the Acadian Variant of the Forest Vegetation Simulator (FVS) to Managed Stands in the Northeast US. National Science Foundation, Center for Advanced Forestry Systems (CAFS) 2012 Annual Meeting, June 26-28, 2012, Bangor, ME.

Weiskittel A.R., B. Rice, J. Wilson and R.G. Wagner. 2012. Improved sampling methods and growth and yield models for partially harvested stands. In Roth, B.E. (Ed.) Cooperative Forestry Research Unit: 2011 Annual Report. University of Maine. Orono, ME. pp. 37-39

Weiskittel, A.R., Russell, M., and Kershaw, J.A. 2012. Development and evaluation of the Acadian Variant of the Forest Vegetation Simulator. ECANUSA Forest Science Conference. Durham, NH. November 1-3.

Zalesny, R.S. Jr., Bauer, E.O., Birr, B.B., Brissette, J., Colombo, S., Eskelin, N., Froese, R.E., Groom, L., Hall, R.B., Headlee, W.L., Isenhart, T.M., Lu, P., Parker, B., Randall, J.A., Swanston, C.W., Wiese, A.H., Zhu, J.Y. 2012. Ecosystem services associated with purpose-grown Populus and Pinus in North America. In: 9th Conference of the International Phytotechnology Society: Phytotechnologies – Plant-based Strategies to Clean Water, Soil, Air and Provide Ecosystem Services, September 11-14, 2012, Hasselt, University, Diepenbeek, Belgium.

Zalesny, R.S. Jr., Bauer, E.O., Birr, B.B., Brissette, J., Colombo, S., Eskelin, N., Froese, R.E., Groom, L., Hall, R.B., Headlee, W.L., Isenhart, T.M., Lu, P., Parker, B., Randall, J.A., Swanston, C.W., Wiese, A.H., Zhu, J.Y. 2012. Assessing the environmental sustainability of plantation Populus and Pinus in North America. In: 9th Biennial Short Rotation Woody Crops Operations Working Group Conference – Woody Crops: Growing a Bioeconomy; November 5-8, 2012, Oak Ridge, TN.

Others (3)

Benjamin, J.G. 2012. Biomass Retention on Mechanized Harvesting Operations. New Hampshire Timberland Owners Association – Timber Crier. December 2012. 1p.

Lilieholm, R.J. Preserving Paradise – Mapping Maine’s Future. 30-minute MPBN television special on the SSI Alternative Futures Project.

Ranco, D., Basket Trees – Saving a Tradition. 30-minute MPBN television special on the SSI Emerald Ash Borer Project.

List of Tables

List of Figures