Annual Report 2014

Center for Research on Sustainable Forests
University of Maine

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

Cover photo by Pam Wells

Table of Contents

Little Guagus Stream from Morrison Ridge Road - photo by Pam Wells

Director's Report

The Center for Research on Sustainable Forests (CRSF) had a very productive year during 2013-14. We were thrilled to have CRSF join five other research units on campus to be selected as a new UMaine Signature Research area supporting **Sustainable Forests & Forest-Based Economy**. This designation will provide a new level of recognition, support, and cooperation for researchers serving the needs of forest landowners and the forest products industry of the state.

As always, our success is driven by our people. **Dr. Brian Roth** along with a number of scientists and over 35 member organizations through the Cooperative Forestry Research Unit (CFRU) made significant progress on a variety of important issues related to Maine's commercial forestlands. **Dr. Jessica Leahy** and her graduate students made excellent progress in advancing our understanding about Maine's family forests. **Drs. Rob Lilieholm** and **Spencer Meyer** did a remarkable job providing decision-making tools related to Maine's conservation forestlands. Spencer Meyer received his PhD this year and has now moved on to a new position at Yale University after 12 years associated with the CFRU and CRSF. Spencer was key to the success of the CFRU and CRSF over the years. His many talents are sorely missed in our program. We wish him the very best in his new position.

Dr. Mohammad Bataineh produced some excellent work on several long-term studies this year. We congratulate him on his new faculty position at the University of Arkansas. **Meg Fergusson** replaced **Kae Cooney** as the new Administrative Assistant for CRSF. We welcome Meg to the program and wish Kae the very best in her new endeavors.

We also welcomed **The Howland Research Forest** as a new research asset into CRSF this year. The Howland Forest is part of the national network of AmeriFlux and FLUXNET sites and has one of the longest records of carbon flux measurements in the world. We look forward to a long collaboration with the **USFS Northern Research Station** in managing this invaluable research site. We are pleased that **John Lee** is now part of CRSF in his position as research associate responsible for management and maintenance of the Howland Research site.

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.

Robert G. Wagner
CRSF Director

Robert G. Wagner

People

Leadership & Staff

Robert Wagner, *Director*

Brian Roth, *CFRU Associate Director*

Jessica Leahy, *Family Forest Program Leader*

Rob Lilieholm, *Conservation Lands Program Leader*

Spencer Meyer *Associate Scientist for Forest Stewardship*

Mohammed Bataineh, *CFRU Post-Doctoral Research Scientist*

John Lee, *Research Associate, Howland Research Forest*

Meg Fergusson, *CRSF Administrative Assistant*

Cynthia Smith, *CFRU Administrative Assistant*

Cooperating Scientists

Jeffrey Benjamin (CFRU)

Daniel Harrison (CFRU, NSRC)

Robert Seymour (CFRU, NSRC)

Aaron Weiskittel (CFRU, NSRC)

Project Scientists

Eddie Bevilacqua, *SUNY College of Environmental Science and Forestry* (NSRC)

Sundew – photoby Pam Wells

Randall Boone, *Colorado State University* (Conservation Lands)

John Brissette, *USF-NRS* (NSRC)

Stephan Colombo, *Ontario Forest Research Institute* (NSRC)

Christopher S. Cronan, *Univ. of Maine* (NSRC)

Anthony D'Amato, *Univ. of Minnesota* (NSRC)

John Daigle, *Univ. of Maine* (NSRC)

Sandra De Urioste-Stone, *Univ. of Maine* (NSRC)

Michael Day, *Univ. of Maine* (NSRC)

Mark Ducey, *Univ. of New Hampshire* (NSRC)

Thom Erdle, *Univ. of New Brunswick* (CFRU)

Ivan Fernandez, *Univ. of Maine* (NSRC)

Shawn Fraver, *Univ. of Maine* (NSRC)

Yellow warbler - photo by Pam Wells

Angela Fuller, *New York Cooperative Fish and Wildlife Research Unit* (CFRU)

Chris Hennigar, *Univ. of New Brunswick* (CFRU, NSRC)

David Hollinger, *USDA Forest Service* (NSRC)

Ted Howard, Univ. of New Hampshire (NSRC)

Tora Johnson, *Univ. of Maine-Machias* (Conservation Lands)

Jennifer Hushaw, *INRS, LLC*. (NSRC)

John Kershaw, *Univ. of New Brunswick* (CFRU)

Laura Kenefic, *USFS-NRS* (NSRC)

Dian H. Kiernan, *SUNY College of Environmental Science and Forestry* (NSRC)

David Kittredge, *Univ. of Mass.* (Family Forests)

Randy Kolka, *USFS-NRS* (NSRC)

Christian Kuehne, *Univ. of Maine* (NSRC)

Kasey Legaard, *Univ. of Maine* (NSRC)

Cunthia Loftin, *USFWS / Univ. of Maine* (CFRU)

Pengxin Lu, *Ontario Forest Research Institute* (NSRC)

Bob Malmsheimer, *SUNY ESF* (NSRC)

Andrew Nelson, *Univ. of Arkansas at Monticello* (NSRC, CFRU)

David Newman, *SUNY College of Environmental Science and Forestry* (NSRC)

Jesse Njoka, *University of Nairobi, Kenya* (Conservation Lands)

Caroline Noblet, *Univ. of Maine* (Family Forests)

Ralph Nyland, *SUNY College of Environmental Science and Forestry* (NSRC)

Joseph Ogulu, *International Livestock Research Institute* (Conservation Lands)

Matthew Olson, *Missouri Department of Conservation* (NSRC, CFRU)

Dave Owen, *Maine Law School* (Conservation Lands)

Bill Parker, *Ontario Forest Research Institute* (NSRC)

Thomas Parr, *Univ. of Maine* (Conservation Lands)

Robin Reid, *Colorado State University* (Conservation Lands)

Andrew Richardson, *Univ. of New Hampshire* (NSRC)

Gabriel Roxby, *Society for the Protection of New Hampshire Forests* (NSRC)

Lindsey Rustad, *USFS-NRS* (NSRC)

Stephen Sader, *Univ. of Maine* (CFRU, NSRC)

Mohammed Said, *International Livestock Research Institute* (Conservation Lands)

Michael Saunders, *Purdue Univ.* (NSRC)

Erin Simons-Legaard, *Univ. of Maine* (NSRC)

Jared Stabach, *Colorado State University* (Conservation Lands)

Susan Stein, *USFS-NRS* (NSRC)

Crista Straub, *Univ. of Maine* (Family Forests)

Brian Sturtevant, *USFS-NRS* (NSRC)

Suraj Upadhaya, *Univ. of Kentucky* (Conservation Lands)

Jennifer Vashon, *Maine IF&W* (CFRU)

Jeremy Wilson, *Univ. of Maine* (NSRC)

Jeffrey Worden, *African Conservation Centre, Nairobi, Kenya* (Conservation Lands)

Ronald Zalesny, *U.S. Forest Service* (NSRC)

GRADUATE STUDENTS

Jon Doty (NSRC)

Stephen Dunham (CFRU)

Rei Hayashi (CFRU)

Patrick Hiesl (CFRU)

Michelle Johnson (Conservation Lands, NSRC)

Cody LaChance (CFRU)

David Mallet (CFRU)

Sheryn Olson (CFRU)

Ben Rice, (NSRC, CFRU)

Brian Rolek (CFRU)

Emily Silver (Family Forests)

Jared Stapp (Conservation Lands)

Kristen Weil (Conservation Lands)

Fox kit – photo by Pam Wells

Financial Report

Income and expenses for the CRSF during FY2013-14 are shown in Table 1. Income supporting the center came from programs administered by or that support the general operations of the CRSF ($1,149,433), as well as extramural grants supporting specific research projects ($585,468) that were received by CRSF scientists from outside agencies. These extramural grants made up 34% of funding for the center and leveraged an additional 66% above CRSF's funding (Figure 1). Total funding of the CRSF for FY2013-14 was $1.73 million.

The proportion of total funding allocated to research projects among the four programs making up the CRSF is shown in Figure 1: Commercial Forests (45%), Family Forests (10%), Conservation Lands (18%), and research projects supported by the Northeastern States Research Cooperative and administered by the CRSF (27%). About 70% of the funding received by CRSF went directly to support research projects described in this report (Figure 1). The remaining 30% supported personnel salaries (25%) and center operating expenses (5%).

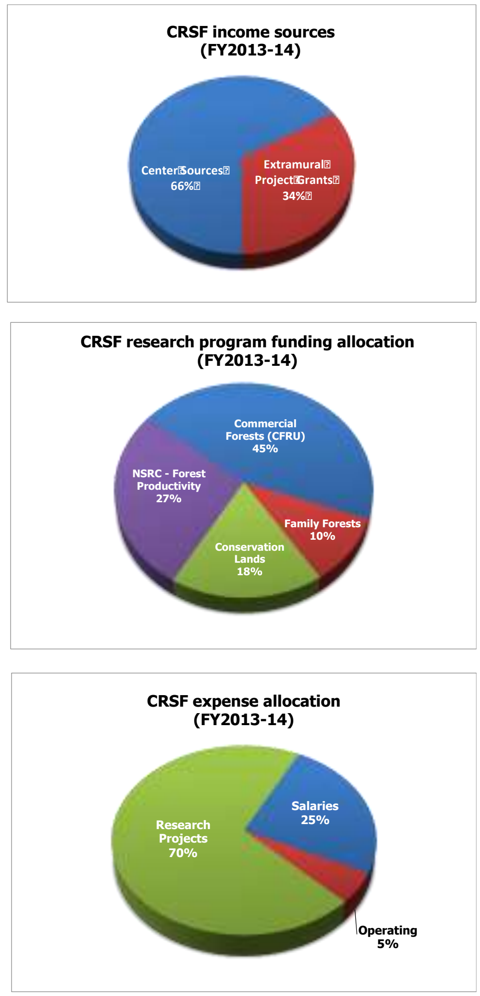


Figure 1. Income sources (top), research program allocation (middle) and expense allocation (bottom) for the CRSF during FY 2013-14.

A key source of financial support for the CRSF is provided by the Maine Economic Improvement Fund (MEIF). The $144,275 investment from MEIF helped leverage $1,005,158 from other CRSF sources and $585,468 in extramural grants for a total of leverage of $1,590,626. This means that every dollar of MEIF fund leveraged $11.02 of additional research funding.

Table 1 FY 2013-14 Budget for the Center for Research on Sustainable Forests

INCOME				
Center Sources:	**Funding Source**	**PI**		**Amount**
Cooperative Forestry Research Unit (CFRU)	CFRU	Wagner	$	506,024
US Forest Service - Northeastern States Research Cooperative - Theme 3 (NSRC)	USDA	Wagner	$	410,574
Maine Economic Improvement Fund (MEIF)	MEIF	Wagner	$	157,866
National Science Foundation - Center for Advanced Forestry Systems (CAFS)	NSF	Wagner / Weiskittel	$	70,000
CRSF Gift Fund	Gift	Wagner	$	2,000
UMaine Munsungan Fund	Gift	Wagner	$	16,560
		Center Total	**$**	**1,163,024**
Extramural Project Grants:				
Maine Sustainability Science Initiative Yr 5	NSF/SSI	Leahy	$	80,000
Sustainable Energy Pathways: Integrated National Framework	NSF	Leahy	$	4,776
Small Woodland Owner Research	SWOAM	Leahy	$	6,500
Sustainable Energy Leaders of the Future	USDA	Leahy	$	14,263
When Natural Disturbance Meets Land Use Change	NSF	Leahy	$	11,775
Alternative Futures Modeling in Maine	NSF-SSI	Lilieholm	$	148,000
RCN-SEES: Scenarios, Services, and Society	NSF	Lilieholm	$	47,000
Penobscot Bay-to-Baxter Initiative	NSF-SSI	Lilieholm/De Urioste	$	10,000
Howland Research Forest	USDA	Wagner / Fernandez	$	97,227
CFRU Extramural Grants from Cooperating Scientist in FY12-13	CFRU	CFRU Scientists	$	165,927
		Extramural Grant Total	**$**	**585,468**
		Total Income	**$**	**1,748,492**

ALLOCATION				
Salaries & Benefits:				
Director, Associate Director, Program Leaders, and Scientists			$	405,517
Support staff + grad students			$	36,891
		Salaries & Benefits Total	**$**	**442,409**
Operating Expenses:			**$**	**91,033**
		Salaries, Benefits, & Operating Total	**$**	**533,442**
Research Projects:	**Funding Source**	**PI**		
CFRU:				
Commercial Thinning Research Network	CFRU	Wagner et al.	$	55,877
Young Hardwood Silviculture Response G&Y Modeling	CFRU	Wagner et al.	$	22,617
Productivity Cost of Logging Equipment	CFRU	Benjamin et al.	$	38,398
Austin Pond: Third Wave	CFRU	Wagner et al.	$	56,481
Extending the Acadian Variant of FVS to Managed Stands	CFRU	Weiskittel	$	18,646
Linking LiDAR to Ground-Based 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 of Forest Management Practices on Forest Bird Communities	CFRU	Harrison	$	28,964
CFRU Extramural Grants from Cooperating Scientist in FY12-13	CFRU	Coop Sci	$	165,927
		Commercial Forests Project Total	**$**	**510,470**
NSF CAFS YEAR 5	NSF	Wagner & Weiskittel	**$**	**70,000**
Family Forests:				
Maine Sustainability Science Initiative Yr 5	NSF/SSI	Leahy	$	80,000
Sustainable Energy Pathways: Integrated National Framework	NSF	Leahy	$	4,776
Small Woodland Owner Research	SWOAM	Leahy	$	6,500
Sustainable Energy Leaders of the Future	USDA	Leahy	$	14,263
When Natural Disturbance Meets Land Use Change	NSF	Leahy	$	11,775
		Family Forests Project Total	**$**	**117,314**
Conservation Lands:				
Alternative Futures Modeling in Maine	NSF-SSI	Lilieholm	$	148,000
RCN-SEES: Scenarios, Services, and Society	NSF	Lilieholm	$	47,000
Penobscot Bay-to-Baxter Initiative	NSF-SSI	Lilieholm/De Urioste	$	10,000
		Conservation Lands Project Total	**$**	**205,000**
NSRC Theme 3:				
Commercial Thinning on Resistance to and Recovery from Defoliation	NSRC	Day	$	78,340
Analysis of Wood Resource Availability	NSRC	Simons-Legaard	$	55,172
Future distribution and productivity of spruce-fir forests under climate change	NSRC	Weiskittel	$	99,502
Quantifying the influence of stand spatial structure and species composition	NSRC	Hushaw	$	79,252
		NSRC Project Total	**$**	**312,266**
		Research Project Total	**$**	**1,215,050**
		Total Allocation	**$**	**1,748,492**

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 build and foster relationships with a wide variety of organizations and their people to achieve common goals. Over the past year we have worked with the following partners:

Ring-necked ducks - photo by Pam Wells

American Consulting Foresters

American Tree Farm System

Ameriflux

Appalachian Mountain Club

Baskahegan Corporation

Baxter State Park, Scientific Forest Management Area

BBC Land, LLC

Canopy Timberlands Maine, LLC

Clayton Lake Woodlands Holding, LLC

Colorado State University

Downeast Lakes Land Trust

EMC Holdings, LLC

Field Timberlands

Forest Society of Maine

Friends of Nairobi National Park

Frontier Forest, LLC

Hilton Timberlands, LLC

Hubbard Brook Research Foundation

Huber Engineered Woods, LLC

International Livestock Research Institute

Irving Woodlands, LLC

Kajiado District Council

Katahdin Forest Management, LLC

Kenya Wildlife Service

Kitengela Ilparakuo Landowners Association

LandVest

Lincoln Paper and Tissue

Maine Bureau of Parks and Lands

Maine Department of Agriculture, Conservation, and Forestry

Maine Department of Inland Fisheries and Wildlife

Maine Division of Parks and Public Lands

Maine Forest Products Council

Maine Tree Foundation

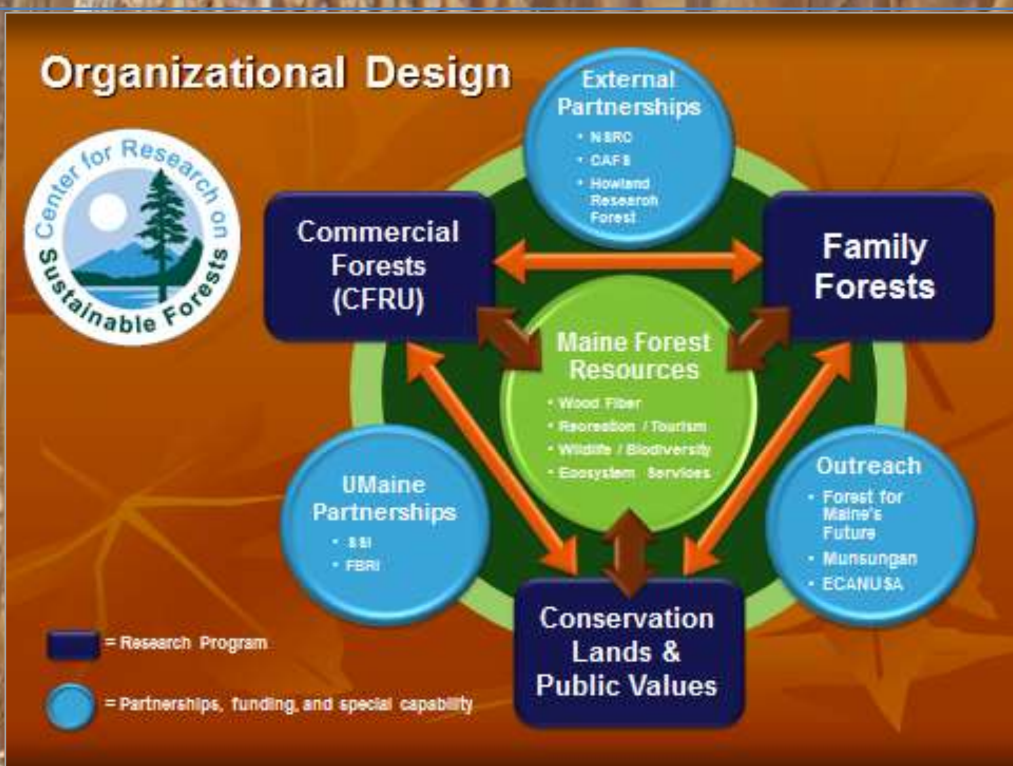
Mosquito, LLC

Narok District Council

Natural Resources Conservation Service
New England Forestry Foundation
North Woods Maine, LLC
Penobscot Experimental Forest
Plum Creek Timber Company, Inc.
Prentiss & Carlisle Company, Inc.
Professional Logging Contractors of Maine
Quebec Ministry of Natural Resources
ReEnergy Holdings, LLC
Robbins Lumber Company
SAPPI Fine Paper
Seven Islands Land Company
Simorg North Forest, LLC
Small Woodland Owners Association of Maine
Snowshoe Timberlands, LLC
St. John Timber, LLC
Sylvan Timberlands, LLC
The Forestland Group, LLC
The Nature Conservancy
Timbervest, LLC
University of Maine, Cooperative Extension
University of Nairobi
University of New Hampshire
University of Vermont, Rubenstein School of Environment and Natural Resources
UPM Madison Paper
USDA, Family Forest Research Center
USDA, Forest Service, Northern Research Station
Wagner Forest Management
White Mountain National Forest
Woodland Pulp, LLC

Dog violet - photo by Pam Wells

CRSF Research Programs



Family Forests Program

Photo by Rob Lilliholm

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 Woodland Owner 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 three general lines of research and outreach over the last year: (1) Developing and implementing social work models of landowner engagement and outreach; (2) Applying risk theory and other social science theories to predict woody biomass supply from family forest lands; and (3) Surveying the knowledge, attitudes, and behaviors of landowners toward invasive forest pests such as the emerald ash borer and Asian long-horned beetle.

Accomplishments include $371,611 in research and outreach funding from a variety of sources including the Northeastern States Research Cooperative, Small Woodland Owner Association of Maine, the U.S. Department of Agriculture, and the National Science Foundation (SSI). Additionally, 11 publications and 3 presentations and workshops led to widespread sharing of research results for maximum impact.

What Works? Evaluating Forest Pest Outreach

Crista Straub, Jessica Leahy, John Daigle, and Sandra DeUrioste-Stone

Giant ichneumon wasp - photo Pamela Wells

Part I. Volunteer Study

Abstract

Early detection of infestations is vital for the success of eradication and containment efforts by limiting the infested area, decreasing the number of trees removed and reducing management costs. Volunteers can play a major role in early detection of invasive forest pests. Research assistants contacted 191 volunteers from Maine, New Hampshire and Vermont. Sixty-five responded: 52 agreed to be interviewed, 10 declined, and three demonstrated interest, but lacked the time to participate. The volunteers were initially contacted by e-mail with follow-up phone calls or emails as needed. Interviews were conducted over the phone and recorded prior to transcription. The interviews yielded information about what motivates and retains forest pest volunteers. Specific improvements to each state's volunteer programs were also identified.

Objectives

Early detection of infestations is vital for the success of eradication and containment efforts by limiting the infested area, decreasing the number of trees removed and reducing management costs. Volunteers can play a major role in early detection of invasive forest pests. Forest Pest Outreach Survey Project (FPOSP) of Maine, the First Detector Program of Vermont and the New Hampshire Cooperative Extension Coverts and Master Gardener Programs are examples of early detection programs in Northern New England. These programs aim to educate and engage the community to prevent infestations of invasive tree-killing pests. However, the impact and efficacy of these outreach efforts have not yet been determined. Volunteer experiences, including motivation and perceived efficacy, may help us better understand what is working, and what needs to be changed so that such program participants may function as effective early detectors of invasive forest pests. This project was designed to determine the motivations and factors behind continued volunteering support and efforts. Our objectives are to identify the problems facing the volunteers of the outreach programs as well as determining how to better equip them for future trainings and outreach through semi-structured interviews. This project has the capacity to enhance invasive forest pest detection and education efforts currently in place and those in the future.

Approach

FPOSP, First Detectors, and Cooperative Extension provided contact information for current and past volunteers who had participated in forest pest trainings or were involved in forest pest outreach. Research assistants contacted 191 volunteers from Maine, New Hampshire and Vermont. Sixty-five responded: 52 agreed to be interviewed, 10 declined, and three demonstrated interest, but lacked the time to participate. The volunteers were initially contacted by e-mail with follow-up phone calls or emails as needed. Interviews were conducted over the phone and recorded prior to transcription. There were six sets of questions, totaling 52 questions in all. On average each phone interview lasted 30 minutes, with several taking as long as an hour. The recorded interview sessions were transcribed verbatim. Following the completion of the phone interviews, the transcriptions were reviewed and analyzed for any major themes, patterns and relationships using qualitative data analysis.

Impacts

The results indicate that:

- Volunteers are mostly positive about their experiences, think the forest pest awareness is important, and enjoy outreach activities. Many volunteers are motivated by their love of the natural world and New England. Some volunteers noted that they were moved by Worcester's experience with Asian longhorn beetle.
- There is variation in the forest pest outreach activities. The volunteers use different strategies and focus on different populations. For some volunteers, forest pests are the focus of their volunteer outreach efforts, while others included forest pest material with other outreach activities. Some volunteers focus their efforts on town officials, others focus on children, and others will talk to anyone who will listen at public events. The variation in strategies helps ensure that many different people are exposed to the forest pest information.
- Most of the volunteers noted that people respond well to short concise materials. Volunteers noted that handouts with large blocks of text and few pictures do not seem to be effective in conveying the message. Photographs are important, both of the potential damage and the insects themselves. Photos of the insects' "look-alikes" are also helpful.
- Hands on activities are important both in training and in outreach. People seem to respond well to models and demonstrations. Volunteers were generally very positive toward any field trips or

field experiences, and other mentioned that there should be more field aspects to the trainings.

- While some volunteers described people calling them with suspicious insects, others were concerned that people will not truly care about forest pests until there is an infestation in their own back yard. Some volunteers noted that it is difficult to know if their outreach activities make a difference.
- Many volunteers said that time is a major barrier to their volunteer efforts. Some felt that they could be more effective if they had more time to give to the program. Some noted that community members are too busy to truly take in their message.
- Recognition and sustained contact remain important in sustaining volunteers' commitments. Volunteers appreciate periodic meetings, trainings and contact. Other volunteers said that it is important the volunteer experience is low pressure and flexible. Most volunteers planned to continue to volunteer with the program in future. Volunteers were uncertain about how to recruit additional volunteers. Some suggested that outdoor-minded people should be targeted.

Part II. Camper Study

Abstract

Since the movement of firewood is a major pathway for EAB and ALB, the goal of this survey was to learn about campers' firewood movement behavior, knowledge and attitudes toward invasive forest pests, and to evaluate the efficacy of different outreach materials and messages through an on-site campground survey. Campground surveys occurred during the summer of 2013. Two undergraduate research assistants visited 18 campgrounds in Maine, New Hampshire and Vermont on Thursdays, Fridays, Saturdays and Sundays between June 20 and September 1. Half of the campgrounds were public, operated by state parks, while half were private campgrounds. The research assistants approached campers present in sites selected systematically, and 272 people agreed to participate: 101 in Maine, 88 in New Hampshire and 83 in Vermont. The results led to recommendations about how to prevent illegal firewood movement through outreach efforts.

Camp fire - photo Pamela Wells

Objectives
Since the movement of firewood is a major pathway for EAB and ALB, the goal of this survey was to learn about campers' firewood movement behavior, knowledge and attitudes toward invasive forest pests, and to evaluate the efficacy of different outreach materials and messages through an on-site campground survey.

Approach
Campground surveys occurred during the summer of 2013. Two undergraduate research assistants visited 18 campgrounds in Maine, New Hampshire and Vermont on Thursdays, Fridays, Saturdays and Sundays between June 20 and September 1. Half of the campgrounds were public, operated by state parks, while half were private campgrounds. The research assistants approached campers present in sites selected systematically, and 272 people agreed to participate: 101 in Maine, 88 in New Hampshire and 83 in Vermont.

Impacts
The results indicate that:

- While most campers did not move firewood, about 30 percent or the campers did report bringing firewood with to the campground. Those staying at public campgrounds were more likely to bring their own firewood than those staying at private campgrounds. Men were also more likely to bring firewood, as well as those with less than a bachelor's degree. Cost, convenience and quality contributed to campers' decision to bring firewood. Campers would be more likely not to bring firewood if they knew that inexpensive, good quality firewood was available for purchase at the campground.
- Most campers have heard about forest pests, especially Asian longhorned beetle, and campers were concerned about the spread of invasive forest pests. Campers have heard messages about the effect of invasive forest pests on the natural world, and laws banning out of state firewood. Campers felt that their actions could make a difference in preventing the spread of the insects.
- Campers reported that they learned about forest pests most frequently by state officials through the media. Effective outreach materials have more pictures than words and clear images of the insects, as well as signs of an infestation.
- Continued outreach, addressing the effects of forest pests, existence of firewood bans, and availability of firewood for purchase can help prevent the spread of invasive forest pests in Northern New England.

Part III. Landowner Study

Abstract
Understanding landowners' current knowledge, risk perception, and concerns about forest pests, such as Emerald Ash Borer and Asian Longhorned beetle, can help develop better response plans and outreach materials. Participants (n = 4,000) were selected at random from publicly available property tax records. The overall response rate was 38 percent. The results showed that landowners had limited knowledge, but high awareness and concern of forest pests. There was strong willingness to support early detection and eradication efforts. Recommendations have been delivered to the Maine Department of Agriculture, Conservation, and Forestry.

Objectives
Much of the land in Vermont, New Hampshire and Maine is owned by small private landowners. In the United States, 35 percent of the forests are owned by families while 55 percent of the forest land in the Northern Region is owned by families (Butler, 2006). Emerald ash borer and Asian longhorned beetle pose a particular risk to such landowners. Early detection, which is an important tool in controlling a potential outbreak, depends on landowners looking for and reporting suspicious insects on their own land. Similarly, an infestation and subsequent treatment, including surveys, quarantines, pesticide application, and tree removal may cause concern for landowners. Landowners may be uncertain as to the implications of an infestation. Understanding landowners' current knowledge, risk perception, and concerns can help develop better response plans and outreach materials.

Approach
This survey consisted of a mailed questionnaire sent to land owners in Maine, New Hampshire and Vermont who own at least 10 acres of property. Participants (n=4,000) were selected at random from publicly available property tax records. We followed a modified Dillman tailored design method (Dilman, 2007). A pre-notification letter was sent out to a random sample of landowners owning more than 10 acres in Maine, New Hampshire and Vermont in September of 2013 alerting participants that a survey would arrive by mail in several weeks. The initial survey packets were sent out at the beginning of October, followed by two reminder post cards. A second mailing of the complete packet to those who had not yet responded occurred in late November, followed by a final thank you and reminder postcard. The overall response rate was 38 percent.

Impacts
The results indicate that:

- Landowners in Northern New England are concerned about forest pests.
- Landowners are not knowledgeable about forest pests.

- Approximately half of respondents were familiar with EAB and ALB.
- Concern increase along with geographic proximity.
- Landowners would like to learn more about how to identify forest pests, where to report an insect, and what to do if they find a suspicious insect.
- Landowners prefer to learn about forest pests through websites and newsletters rather than social media.
- Most have not looked for forest pests, but many plan to do so in the future, especially after reading outreach material about forest pests.
- Most respondents would report a suspicious insect if they found one.
- Landowners think that it is likely that EAB or ALB will be found in their communities within the next five to ten years.
- Landowners think that forest pests will influence the forest products industry.
- Many landowners are willing to allow professionals to look for forest pests on their land.
- Landowners prefer to understand the rationale and objectives of forest pest response plans.
- There is significant uncertainty about forest pests and their implications.

Polyphemus moth - photo by Pam Wells

Functioning Family Forests Project

Jessica Leahy

Abstract

This project investigates how conservation issues may benefit from a social work approach to landowner outreach and engagement. Our objectives included developing a family forest-specific wraparound case management process and implementing it with family forest landowners. We also assisted the Small Woodland Owner Association of Maine succession planning efforts by providing social work expertise during two workshops. We organized initial peer-to-peer learning opportunities in the rural southern Maine community of Baldwin. Student research assistants prepared a cultural competency training program for natural resource professionals that increases cultural competency to provide conservation services. Finally, an undergraduate research assistant on the project began efforts to study the feasibility of a wood bank.

Peer-to-peer network meeting in Baldwin, Maine
photo Pamela Wells

Objectives

Our objectives included developing a family forest-specific wraparound case management process and implementing it with family forest landowners. The wraparound process has been used in many social work contexts and is: team-based, values the voice and choice of the landowners, culturally competent, focused on incremental progress, strength-focused, involves community support, and uses science-based interventions. We also assisted the Small Woodland Owner Association of Maine succession planning efforts by providing social work expertise during two workshops. We organized initial peer-to-peer learning opportunities in the rural southern Maine community of Baldwin. An objective involved preparing a cultural competency training program for natural resource professionals. Our final objective was to examine the possibilities of a wood bank in the Baldwin area.

Approach

Achieving environmental conservation is a complex endeavor. While it is tempting to focus on environmental goals and outcomes, many conservation issues are intertwined with social and economic factors. Natural resource professionals, such as foresters, are equipped to help landowners make decisions about land management – which trees should be harvested, how large of a buffer should be placed near a stream, which properties are the highest priorities for an easement, etc. However, many of the challenges that landowners face are human in nature and, in particular, involve family dynamics. Our approach to this project investigates how solving these conservation issues may benefit from a social work approach. Take for instance the challenges a low-income landowner and his/her family may face in enrolling and participating in the Tree Growth Tax Law in order to reduce his/her taxes. The family must agree on timber harvesting as their primary objective, and then the landowner must navigate a system of service providers, bureaucracies, and paperwork including employing a professional forester to prepare a management plan, participating in federal cost-share programs, periodically working with a logger, and notifying the town government. Another decision that landowners face is what to do with their land once they pass away. Here, landowners must make decisions about the future of their family forests and then take legal and communication steps to implement their plan. In these cases, and others, a social work approach to implementing conservation initiatives may lead to more efficient and effective outcomes than traditional forestry solutions like management plans and outreach materials. This innovative, unique approach to conservation has been untested to date.

Impacts

Two social work students and one ecology and environmental sciences student were hired to work in the community of Baldwin. A wraparound process was designed and forums were held to encourage community participation. A succession planning workshop helped landowners plan for the future of their land after they pass away. We partnered with the Maine Forest Service to arrange peer-to-peer learning opportunities. Social work students prepared a cultural competency training program for natural resource professionals that increases cultural competency to provide conservation services. An undergraduate research assistant on the project began efforts to study the feasibility of a wood bank. Jessica Leahy and Pam Wells, the licensed clinical social worker supervising the social work students, were awarded the 2014 Field Instructors of the Year by the UMaine Social Work Department. In the fall, a presentation will be made at the Society of American Foresters Convention sharing the approach and impact of this project.

Tree farm in the Bangor area – photo by Michael Quartuch

An Evidence-based Review of Timber Harvesting Behavior Among Private Woodland Owners

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

Abstract
Understanding private woodland owner timber harvesting behavior is essential to measuring and predicting worldwide timber supply. This review synthesizes existing private woodland owner literature from North America and Europe. Over 100 articles from 1970–2014 that were published in peer-reviewed journals, government reports, and dissertations were analyzed, determining trends, broad themes, and opportunities for future research. Our objectives were to: (1) identify how past research defined and analyzed harvesting behavior; (2) describe the evolution of these methods; (3) describe the significant predictors of timber harvesting; (4) determine the extent to which previous research linked land owners' stated attitudes to observed harvesting behavior; and, (5) suggest opportunities for future research. Results indicate that parcel size, harvest price, and distance from residence were the most common significant predictors of harvesting behavior. Additionally, researchers believe a mix of qualitative, quantitative, and ground-truthing (e.g. field visits) methods are best, but few studies utilize all. Many studies purportedly studied behavior, but actually measure stated preference or attitudes. There was a very low evidence rating overall; few studies validated stated preferences or attitudes by measuring observable harvesting behaviors. A better understanding of small woodland owner behavior will inform timber supply prediction and support forest management outreach efforts.

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) describe the significant predictors of timber harvesting; (4) determine the extent to which previous research linked land owners' stated attitudes to observed harvesting behavior; and, (5) suggest opportunities for future research. This project is complete.

Approach

We synthesized 118 articles from 1970–2013 that were published in peer-reviewed journals, government reports, and dissertations, using an evidence-based framework. Articles were gathered using snowball sampling from major scientific search engines, and supplemented with Internet research on state and federal forest management programs. We assigned quality of evidence ratings to each publication with the highest quality being studies that measured actual timber harvesting behavior and the lowest quality of evidence assigned to publications measuring only timber harvesting attitudes.

Results

Timber harvesting behavior literature has increased over time with the vast majority of papers using a mail survey or an empirically-based economic model. Of the 81 articles that focused on timber harvesting behavior, 25 used a statistical technique that predicted intended or actual timber harvesting behavior. The variables that significantly predicted timber harvesting were parcel size, total forested acres, living on the forested land, and income. 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 believe future studies of private woodland owner timber harvesting behavior should explicitly link 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.

Resolving a Critical Question in Predicting Woody Biomass Supply to the Northern Forest industry: Understanding Willingness to Harvest from Small Woodland Owners

Emily Silver, Jessica Leahy, Aaron Weiskittel, Caroline Noblet

Abstract

Predicting and understanding timber supply is one central component to the viability of the bioenergy industry. This study seeks to understand the knowledge, attitudes, and willingness to harvest timber for bioenergy markets. Thirty-two semistructured interviews were conducted with private woodland owners who had previously harvested timber, had never harvested timber, and had harvested timber for woody biomass markets. Results indicate that private woodland owners have little knowledge of biomass harvesting, but a desire to learn more. Attitudes toward biomass harvesting are mixed, with negative attitudes about nutrient removal, poor economics, and it being a poor end-use for wood products. Positive attitudes towards biomass pertained to fossil fuel replacement, a use for low-quality wood, and strengthening Maine's forest economy. Some owners expressed a willingness to supply timber for biomass, but not all that had harvested for bioenergy markets would do so again. These results help provide insight to available timber supply for the bioenergy industry and provide an assessment of landowner awareness of timber harvesting options.

Small woodlot tour - photo by 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 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.

Approach

We conducted 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 conducted semi-structured interviews with 32 landowners owning between 10-2,800 acres in Maine, Vermont, and New Hampshire. We recruited interview participants using the networks within landowner associations, state forestry agencies, Cooperative Extension, and others. Interviews were conducted in person, whenever feasible and lasted between 45 minutes to an hour. Participants were compensated 25 dollars for their time and Institutional Review Board approval was obtained prior to the study.

Preliminary Results

Definitions of biomass harvesting and bioenergy are highly variable and typically concern the type of harvest or the post-processing of woody materials. Knowledge of biomass harvesting and the bioenergy industry in Maine is low while desire for more information is high. Attitudes toward biomass harvesting are mixed, with negative attitudes about nutrient removal, poor economics, and it being a poor end-use for wood products. Positive attitudes towards biomass pertained to fossil fuel replacement, a use for low-quality wood, and strengthening Maine's forest economy. Willingness to harvest biomass was low, and often context dependent (e.g. if another harvest were taking place already). Reactions to biomass harvesting scenarios (i.e. transportation, destination, end use, byproduct use) revealed that the majority of landowners do not care what happens after the wood leaves their property. Those that cared were primarily concerned that the energy recovered from their wood did not exceed the energy used to make a particular product. The landowners who had harvested biomass for bioenergy production were not qualitatively different from those who had not. They still expressed negative attitudes and sometimes an unwillingness to harvest despite having harvested for bioenergy previously. Risks to the forest included diseases and pests, development pressure

Impacts

Our understanding of landowner willingness to harvest biomass will help inform policy makers and the forest products industry about the availability of biomass from privately owned woodlands. This supply is central to the feasibility of biomass as a renewable energy option.

Program on Conservation Lands & Public Values

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 nongovernmental groups, including nearly 100 land trusts.

Middle Oxhead Pond - photo Pam Wells

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 across the overall landscape.

CRSF's research program on Conservation Lands & 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. As an important step in realizing these goals, we have just released the Maine Futures Community Mapper – an award-winning online tool for assessing land use for forestry, agriculture, conservation and development across two large watersheds covering 4.4 million acres in Maine. To learn more, visit MaineLandUseFutures.org.

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

Robert J. Lilieholm, Christopher Cronan, Spencer Meyer, Michelle Johnson, Dave Owen, and Thomas Parr

Abstract

We developed stakeholder-derived land use suitability scores for nearly 4.5 million acres in two large Maine watersheds. The suitabilities, developed using Bayesian Belief Networks to integrate expert opinion and geospatial data, identify areas conducive to forestry, agriculture, conservation and development. A set of five alternative development scenarios were generated with stakeholder input to portray a range of develop options likely to occur over the next 30 years, identifying potential conflicts and compatibilities between our four land uses. Our research is available to the public through an interactive website (see www.MaineLandUseFutures.org), and recently won the President's Research Impact Award at the University of Maine.

Objectives

The U.S. Forest Service projects that by 2030, both the Lower Penobscot and Lower Androscoggin River watersheds in Maine 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.

Approach

Since 2010, the research team has led focus groups on each of our four land uses with more than 70 stakeholders. 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.

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 2),

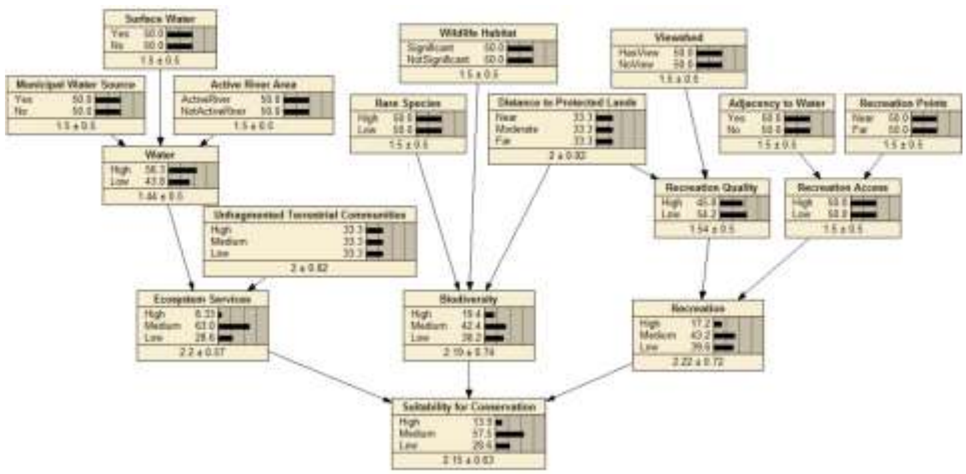


Figure 2. Bayesian belief network influence diagram showing relationship between factors contributing to overall suitability for ecosystem conservation.

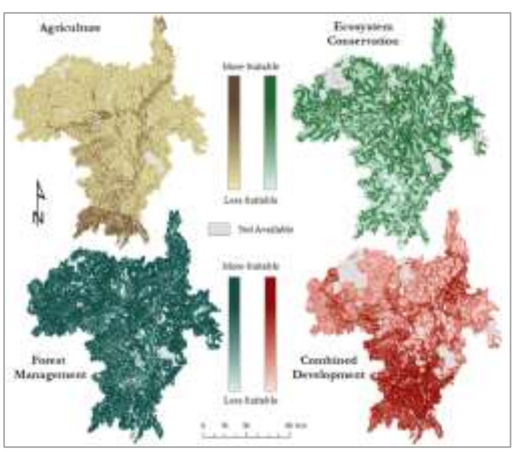


Figure 3. Land use suitability for four land uses in the Lower Penobscot River Watershed.

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 (Figure 3).

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. A set of future development scenarios were generated with our stakeholder partners (Figure 4). 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.

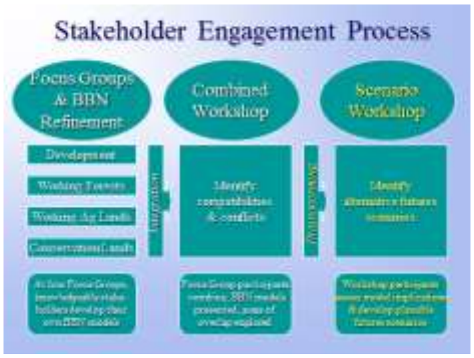


Figure 4 Conceptual model describing the stakeholder engagement process used for focus groups representing each land use

Results

Based on our four land use suitability models, we have explored the potential for future conflict and compatibilities in the 2.5-million-acre Lower Penobscot River Watershed. For example, Figure 5 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.

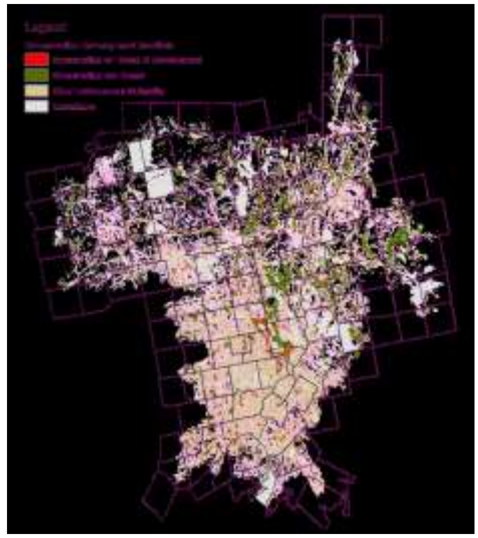


Figure 5 Areas highly suitable for conservation, development, and both which indicates potential conflicts

In Figure 6, 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 7, 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

Figure 6 Areas of potential conflict for forestry and development

Figure 7 Areas of opportunity suitable for both forestry and conservation objectives

development. Indeed, working forest management and ecosystem conservation are often complementary. Conservation non-profit organizations in Maine hold nearly 2 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.

Finally, Figure 8 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

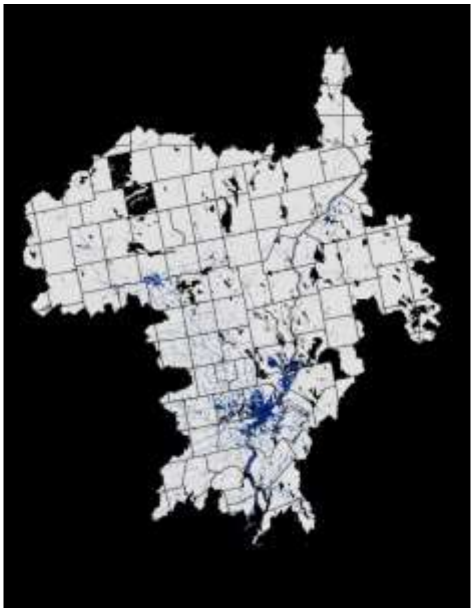


Figure 8 Blue areas indicate land suitable for development, but which are not highly suitable for other land uses

underutilized. Identifying lands suitable for development that leverages existing community assets has the potential to mitigate losses to traditional land uses while keeping tax rates low.

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 research goes beyond typical conservation planning by evaluating an array of possible futures across multiple land uses. These results are available on-line through the Maine Futures Community Mapper (MFCM – see www.MaineLandUseFutures.org), which helps communities and conservation organizations better prioritize their protection efforts while allowing policy makers and planners to consider alternate policy strategies.

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.

Stillwater River, Orono, Maine - photo Pam 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, Dave Owen, Mohammed Said

Abstract

We are using hourly GPS location data from 36 collared wildebeest in three Kenyan protected areas to understand seasonal migration trends. These trends will be modeled in an agent-based modeling environment to study the impacts on herd viability of different climate change and future development and fencing scenarios.

Objectives

Kenya's Athi-Kaputiei Plains (AKP) cover over 2,590 km^2 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 9) (Mundia and Aniya 2005).

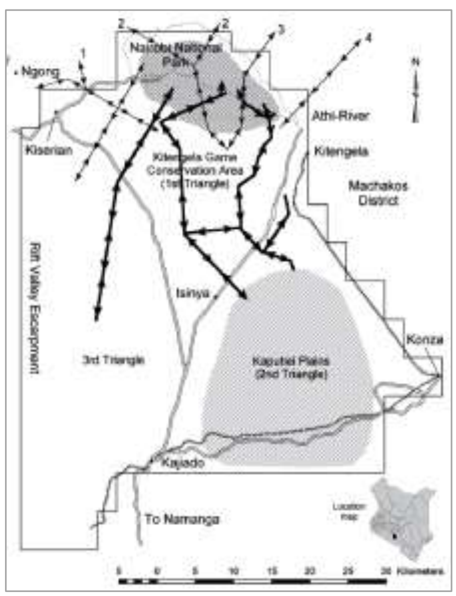


Figure 9 Historic (thin solid lines and arrows, numbered) and current (bold solid lines and arrows) wildlife and livestock grazing routes. Migratory species like wildebeest form a critical link in the ecosystem's food chain.

Our core research hypotheses are:

H1 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.

H2 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 are using 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 10 and Figure 11). Consequently, historic northern migration routes for wildebeest 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.

Thus far, 36 wildebeest have been collared with GPS trackers across our three study areas (see project website, Gnu Landscapes, at: http://www.nrel.colostate.edu/projects/gnu/). In-depth analyses of wildebeest movement are still pending, but differences

Figure 10 Ktengela 2003

Figure 11 Kitengela 2013

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. Forage 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. 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 12a through e). These 2040 scenarios include: (a) current trend; (b) trend with smart growth development; (c) trend with increased development; (d) trend with increased smart growth development; and (e) trend with increased development with transportation infrastructure (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. In spring 2014, a major project output was a set of five policy briefing papers addressing different fencing and development issues in the region. These summaries were requested by the Governor of Kajiado County, Dr. David Nkedianye.

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 Athi-Kaputiei 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. We will contribute to broader societal goals by providing critical information to local and national policy processes in Kenya, and will continue to 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.

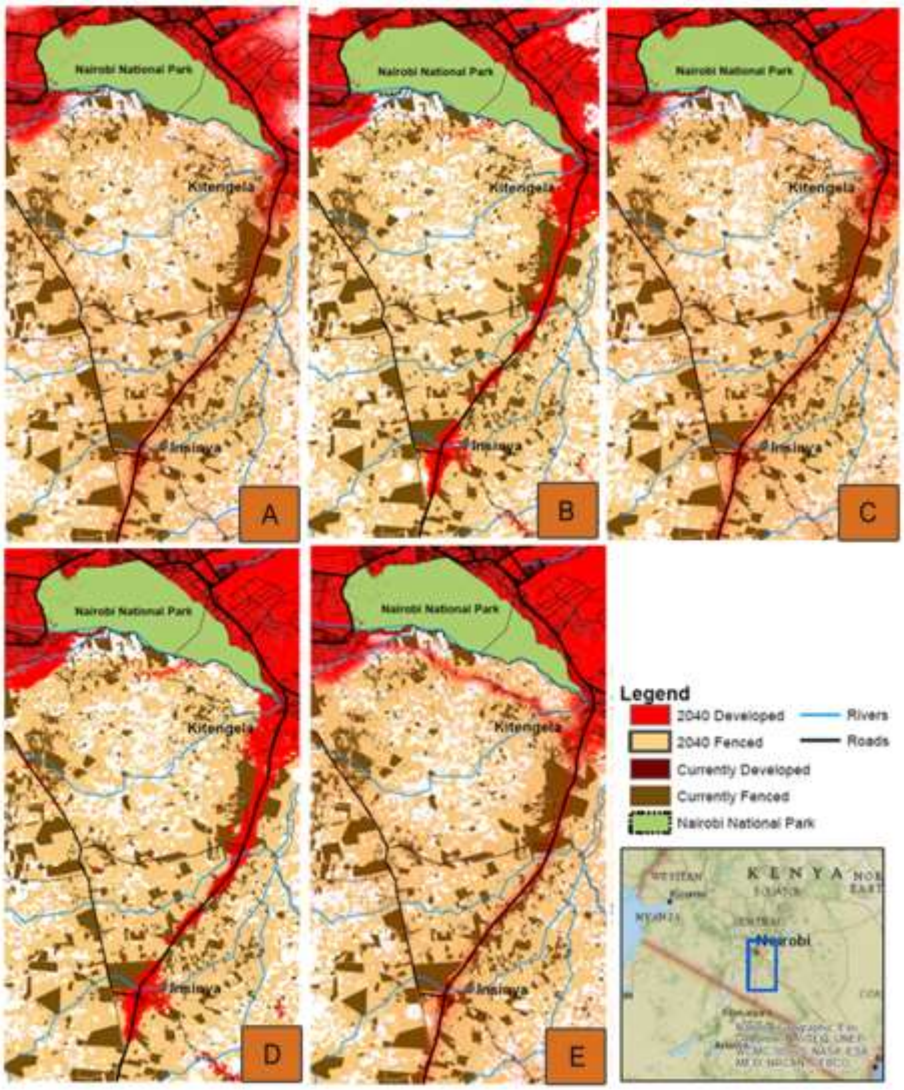


Figure 12 Nairobi Alternatives Futures Study development and fencing by 2040 in the region south of Nairobi National Park under five alternative futures scenarios. A: Current Trend; B: Trend with Smart Growth; C: Trend with Increased Development; D: Trend with Increased Smart Growth Development; E: Trend with Increased Development and Transportation

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.

Mapping Forest Dynamics in the Buffer Zone of Chitwan National Park, Nepal

Jared R. Stapp, Robert J. Lilieholm, Suraj Upadhaya, and Tora Johnson

Introduction

Forests, which cover one-quarter of Nepal, have witnessed a long history of degradation due to settlement from rising human populations, agricultural expansion, and timber harvest. Historic rates of loss, if continued, pose a significant threat to rural populations that depend on forests for subsistence use, as well as Nepal's biodiversity, wildlife habitat, environmental resources, and the functioning of complex ecological systems. Also at risk are downstream users such as the quickly growing population of India. A Master Plan for the Forestry Sector, enacted in 1989, laid the foundation for community-based forest management. Anecdotal evidence suggests that these policies have been effective in slowing and even reversing forest loss in parts of Nepal. Here, we use Landsat imagery for the years 1989, 2005 and 2013 to compute a Normalized Difference Vegetation Index (NDVI) to determine trends in forest cover for buffer zone communities surrounding Chitwan National Park (CNP). The analysis, covering over 3,000 km^2, found that since 1989, there has been a clear trend of first, continued decline of forest cover, followed by a significant amount of regeneration. This study spatially quantifies forest cover and offers insight into the success of modern forest management policies and supporting institutions by highlighting the reversal of forest loss in recent years.

Methods

Remote sensing techniques and satellite imagery were used to quantify the amounts of forest loss and gain between 1989 and December 2013 in CNP and its 36 buffer zone Village Development Committees (VDCs). The UN initiative on Reducing Emissions from Deforestation and forest Degradation (REDD) found that overall forest loss in Nepal fell to zero percent annually between 2005 and 2010. For this reason, an intermediate year, 2005, was used to compare the two periods – i.e., 1989-2005 and 2005-2013 – to explore the shifting trends in forest loss (Table 2 Remote sensing/GIS data used in this study). Using Landsat satellite imagery, NDVI was computed for the years 1989, 2005, and 2013 to compare changes in forest cover. The analysis was conducted for CNP (including the adjacent Parsa Wildlife Reserve), and the 36 VDCs in its buffer zone to see which VDCs have experienced the greatest levels of forest loss and forest growth. Importantly, the Landsat scenes that were used for this analysis were all from the same time of year, selected to be as close to one another in time as possible.

Table 2 Remote sensing/GIS data used in this study

Satellite & Data	Path	Row	Date	Bands (wavelength in micrometers)	Source
Landsat 5 TM	141	41	Oct. 31, 1989	• Band 3 Visible Red (0.63 - 0.69 µm) • Band 4 Near-Infrared (0.76 - 0.90 µm)	USGS Glovis
Landsat 5 TM	142	41	Nov. 7, 1989	• Band 3 Visible Red (0.63 - 0.69 µm) • Band 4 Near-Infrared (0.76 - 0.90 µm)	USGS Glovis
Landsat 5 TM	141	41	Nov. 12, 2005	• Band 3 Visible Red (0.63 - 0.69 µm) • Band 4 Near-Infrared (0.76 - 0.90 µm)	USGS Glovis
Landsat 5 TM	142	41	Nov. 19, 2005	• Band 3 Visible Red (0.63 - 0.69 µm) • Band 4 Near-Infrared (0.76 - 0.90 µm)	USGS/Glovis
Landsat 8 OLI-TIRS	141	41	Nov. 25, 2013	• Band 4 Visible Red (0.64 - 0.67µm) • Band 5 Near-Infrared (0.85 - 0.88 µm)	USGS Glovis
Landsat 8 OLI-TIRS	142	41	Dec. 4, 2013	• Band 4 Visible Red (0.64 - 0.67µm) • Band 5 Near-Infrared (0.85 - 0.88 µm)	USGS Glovis
CNP and VDC Shapefile			Acquired Sep. 2013		GADM, 2012

Results

NDVI analysis revealed that buffer zone VDCs lost 9.9% of total forest cover between 1989 and 2005, and regained 7.4% between 2005 and 2013; the overall loss between 1989 and 2013 was 3.1% (Table 2). T-tests revealed a significant difference in means for percent of total area forested and total number of forested hectares per VDC between 1989 and 2005, and 2005 and 2013. A significant difference was not found between 1989 and 2013, suggesting that the total forest cover in the area has regenerated after a long period of steady decline; however, the ecological characteristics of the regenerated forest is likely to vary significantly from earlier times. Highest quantities of loss and regeneration were found in the north-central buffers of CNP, the area that has experienced the highest rates of human population growth and development (Figure 13 through 16).

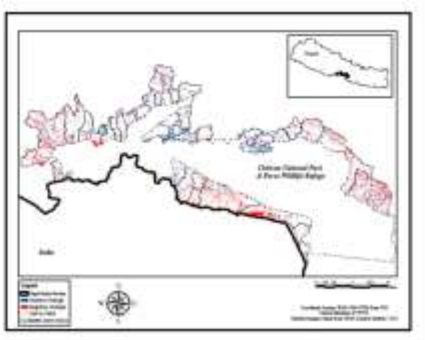


Figure 13 Remote sensing/GIS data used in this study

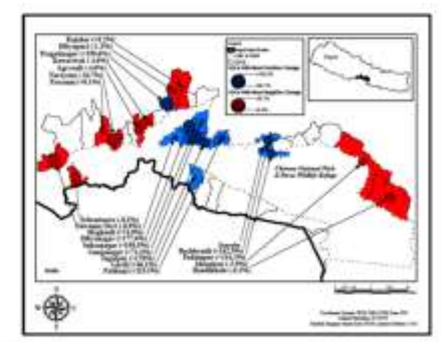


Figure 14 VDC's with the most forest loss and gain 1989-2005

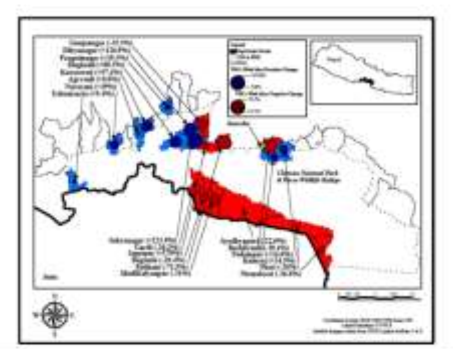


Figure 15 VDC's with the most forest loss and gain, 2005-2013

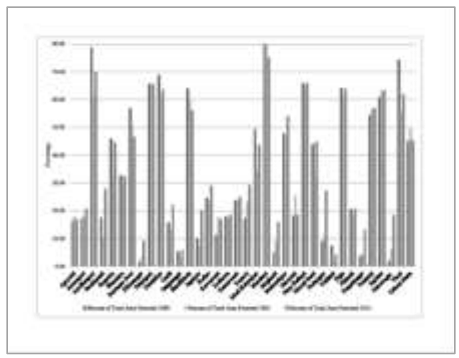


Figure 16 Percent of total forested per VDC

Conclusions and Future Work

Nepal's long history of forest loss appears to be reversing. Indeed, according to the World Bank (2013), forest cover in Nepal was constant at 25.4% in 2009, 2010, and 2011. Here, we found that rates of forest loss observed between 1989 and 2005 slowed considerably in the 2005 -2013 period, with significant regeneration observed in many portions of our study area. The reversal of forest loss in many parts of Nepal appears to be in response to a combination of factors – primarily revised forestry legislation in YEAR that devolved forest oversight to the community level and encouraged local populations to take a more active role in resource management.

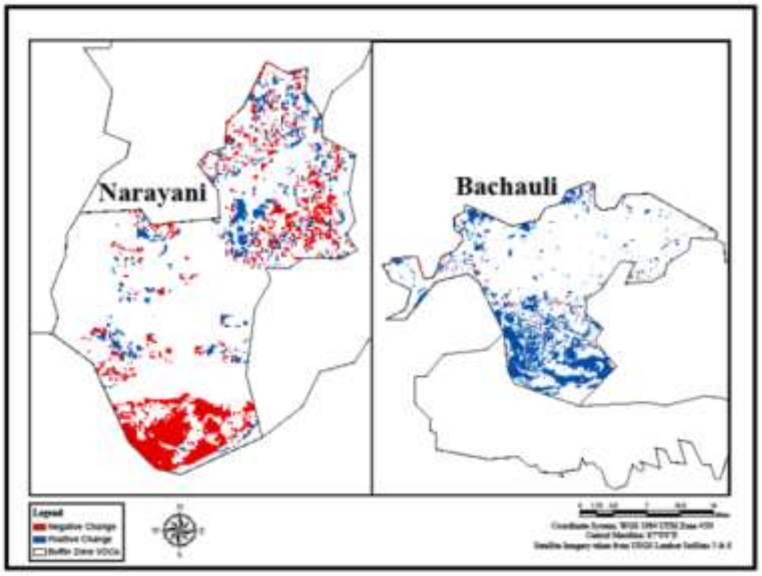


Figure 17 Narayani and Bachauli, the VDCs exhibiting the most forest loss and gain, respectively, in recent years

Current work under this project is now examining how, at the community level, these changes in forest policy have impacted not only the forest resource (as shown here), but the communities and people that rely on a wide range of benefits and services that these forests provide. Indeed, the remote sensing work presented here was used to design a household survey conducted in the summer of 2014 to assess community needs, perceptions, and attitudes towards collective action, the adoption of conservation-oriented behaviors, and community-based forest management practices and policies. An important component of the survey was to discover what demographic/economic/policy 'boundaries' exist in the two VDCs that have witnessed the most forest loss and gain between 2005-2013, respectively (i.e., the communities of Narayani and Bachauli; see (Figure 17). Initial results of that work, which will be used to parameterize an agent-based model to explore sustainable forest management strategies, found that resident perceptions of forest change closely matched the findings of our remote sensing analysis.

References

The United Nations collaborative initiative on Reducing Emissions from Deforestation and forest Degradation (REDD). (2014). REDD in Nepal. Retrieved from http://theredddesk.org/countries/nepal.

World Bank. (2013). World Bank Indicators – Nepal – Land Use. *Trading Economics*. Retrieved from http://www.tradingeconomics.com/nepal/forest-area-percent-of-land-area-wb-data.html

Commercial Forests CFRU

Maine's commercial forests cover the northern half of the state and provide the backbone of the state's annual $8 billion forest products economy. These private landowners manage large tracts of land that involve complex decisions about a wide variety of forest resource issues over long periods of time. To help meet this challenge, these landowners recognized the need long ago for a strong applied research program to provide new information about how to best manage their lands. As a result, they partnered with the University of Maine in 1975 to form the Cooperative Forestry Research Unit (CFRU).

The mission of the CFRU is to *"conduct applied scientific research that contributes to the sustainable management of Maine's forests for desired products, services, and conditions."* Currently composed of 34 private and public forestland management organizations, wood processors, conservation organizations, and other members, the CFRU guides and supports research on key issues facing Maine's forest landowners and managers. These members represent 8.3 million acres, or half of Maine's forestland. The CFRU is one of the oldest industry / university forest research cooperatives in the United States, and serves as a model for stakeholder-driven research at the University of Maine.

This year, the CFRU raised $506,024 in member contributions and leveraged an additional $235,927 (26%) 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.

CFRU Members:

Appalachian Mountain Club

Baskahegan Corporation

Baxter State Park, SFMA

BBC Land, LLC

Canopy Timberlands Maine, LLC

Clayton Lake Woodlands Holding, LLC

Downeast Lakes Land Trust

EMC Holdings, LLC

Field Timberlands

Forest Society of Maine

Frontier Forest, LLC

Huber Engineered Woods, LLC

Irving Woodlands, LLC

Katahdin Forest Management, LLC

LandVest

Maine Bureau of Parks & Public Lands

Mosquito, LLC

New England Forestry Foundation

North Woods Maine, LLC

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

The Forestland Group, LLC

The Nature Conservancy

Timbervest, LLC

UPM Madison Paper

Wagner Forest Management

Red pine stand, Morrison Ridge Road - photo by Pam Wells

CFRU PROJECT SUMMARIES

Extending the Acadian Variant of the Forest Vegetation Simulator to Intensively Managed Stands

Aaron Weiskittel, John Kershaw, and Chris Hennigar

Forest managers rely on growth and yield models to assess whether their short-term plans will meet long-term sustainability goals. The Acadian variant of the Forest Vegetation Simulator (FVS) is currently being tested and showing good performance across a range of stand types. However, the model was mostly developed using data from naturally-regenerated stands and the primary management activities represented are various commercial thinning regimes. Consequently, intensive management activities like vegetation control, pre-commercial thinning (PCT), commercial thinning (CT), and genetics are not well represented. The overall goal of this project is to extend the Acadian variant of FVS to intensively managed stands in the region.

Testing the Ability of LIDAR to Predict Various Forest Inventory Attributes in Managed Stands of Maine

Rei Hayahsi, Aaron Weiskittel, Steve Sader, and John Kershaw

The objective of this study was to investigate the applicability of low density (1-3 pulses per square meter) LiDAR data at the Penobscot Experimental Forest to predict inventory attributes on an area- and individual tree basis. Specifically, this study focused on for predicting maximum tree height, stem density, basal area, quadratic mean diameter, and total volume to use an area-based method. For the individual tree based approach, species classification as well as total height and volume predictions were made. Results suggest that low density LiDAR can be used as a supporting tool in forest management in the Acadian Region if the focus is on stand-level attributes.

Snowshoe hare – photo by Pam Wells

Relationships among Forest Harvesting, Snowshoe Hares, and Canada Lynx in Maine

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

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 is threatened in the lower 48 U.S. states and in New Brunswick, Canada. This report documents results from the monitoring and assessment of snowshoe hare density, seasonal habitat use and Canada lynx seasonal prey composition.

Bird Communities of Coniferous Forests in the Acadian Region: Habitat Associations and Response of Birds to Forest Management

Brian Rolek, Daniel Harrison, and Cynthia Loftin

Several bird species of concern thrive in the coniferous forests of Northern New England with the U.S. federal government authorized to manage these species under the U.S. Migratory Bird Treaty Act. While Maine contributes up to 96% of breeding habitat for some of these spruce-fir associated species, their habitat requirements and responses to forest management remain poorly understood. This project uses a series of forest bird community surveys to provide information about habitat associations, how these associations are influenced by management, and which habitat attributes can be promoted to manage species of concern in the future.

Black poll warbler - Photo by Pam Wells

Modeling Young Hardwood Responses to Silviculture

Andrew Nelson, Robert Wagner, and Aaron Weiskittel

The total amount and distribution of leaves along the length of crowns varies by species and is a key driver in the competitive advantage of one species over another. In order to better predict the performance of individual trees in mixed species stands in the Acadian region, a better understanding of how species and silvicultural intensity affects the leaf area development of young hardwood trees is needed. Using data from the SIComp study site on the Penobscot Experimental Forest, equations were developed for five naturally regenerated hardwood species (red maple, gray birch, paper birch, bigtooth aspen, and trembling aspen) that can be incorporated into growth and yield models

Patch Occupancy, Habitat Use, and Population Performance of Spruce Grouse in Commercially Managed Conifer Stands

Stephen Dunham and Daniel Harrison

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 across a range of stand conditions is ongoing and consists of occupancy surveys, home range analysis of broods, and monitoring of survival and brood rearing success of adult females.

Canada warbler - photo by Pam Wells

Partnerships & Initiatives

An important dimension of the CRSF's mission is collaboration with other programs that can help advance research on various aspects of forest resources. These initiatives and partnerships strengthen our overall mission by leveraging funds, facilities, and talent, as well as fostering interdisciplinary cooperation on key issues facing forest resources.

For example, the CRSF leads Theme 3 of the **Northeastern States Research Cooperative (NSRC)**, which provides competitive research funding for projects that advance understanding about forest productivity. The CFRU is part of the National Science Foundation's **Center for Advanced Forestry Systems (CAFS)**, which provides funding with nine other industry/university forest research cooperatives across the country. CRSF is the home for the **Howland Research Forest**, which is part of the national Ameriflux network measuring the atmospheric flux of carbon dioxide. CRSF is also a partner in **Forests for Maine's Future**, which provides a social media and website connection on important forest resource issues with the general public. In addition, CRSF partners directly with other UMaine research centers on collaborative projects, including the **Sustainability Solutions Initiative (SSI)** and **Forest Bioproducts Research Institute (FBRI)**.

In addition to the aforementioned stakeholders, this year CRSF participated in the following strategic partnership and initiatives.

The Northeastern States Research Cooperative (NSRC)

The Northeastern States Research Cooperative (NSRC) is a competitive grant program funded by the USDA Forest Service that supports cross-disciplinary, collaborative research in the Northern Forest — a 26-million acre working landscape that is home to more than one million residents and stretches from eastern Maine through New Hampshire and Vermont and into northern New York. The NSRC addresses the importance of the Northern Forest to society and the need for research to have relevance and benefit to the people who live there, work with its resources, use its products, visit it, and care about it.

The program is jointly directed through the USDA Forest Service, Northern Research Station, and a designated institution in each of the four Northern Forest states: The Rubenstein School of Environment and Natural Resources at the University of Vermont, the University of New Hampshire in cooperation with the Hubbard Brook Research Foundation in New Hampshire, the Center for Research on Sustainable Forests at the University of Maine, and the State University of New York College of Environmental Science and Forestry.

Since 2001, the NSRC has awarded over 295 research grants, totaling over $22 million, to researchers throughout the region. Each year, the NSRC supports Northern Forest research that fits into four research 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*

Theme 3 at CRSF

NSRC Theme 3 is managed by the CRSF and supports research that will quantify, improve, and sustain productivity of the products-based economy of the Northern Forest. Aspects of primary interest include underlying biological processes, management practices, and methods of prediction that will influence future wood supplies and forest conditions. Dr. Bob Wagner and Meg Fergusson manage the NSRC within CRSF.

During FY 2013-14, four new project proposals on the Northern Forest were approved for funding through Theme 3, while CRSF continues to support over a dozen ongoing NSRC projects granted in past years. Summaries of the final reports from past projects and progress reports from current Theme 3 projects follow (full reports available on the NSRC web site at nsrcforest.org).

NSRC THEME 3 FINAL REPORT SUMMARIES

Climate Change Consequences of Forest Management Practices

Principal Investigator: David Y. Hollinger, *USDA Forest Service, Northern Research Station*
Co-PI: Andrew Richardson, *University of New Hampshire*

Forestry may yet play an important role in policy responses aimed at reducing climate-warming greenhouse gases. This is because when forests grow they remove from the atmosphere the principal greenhouse gas, carbon dioxide, and store it as carbon in wood and other biomass. Payment for carbon storage has been discussed as a potential incentive for forest owners to manage their lands to take up and store carbon. There are many unresolved scientific and policy issues relating to such schemes and how they might affect present forest management practices. A recent scientific concern relates to the consequences of afforestation and the decrease in the reflectivity (albedo) of a forested land surface compared to crops or grassland, and the impact that these changes in albedo may have on the climate system. In essence, snow covered fields reflect away more winter sunlight than evergreen forests, so planting forests could lead to the absorption of more solar energy and further warming of the climate system. However, the climate models that are used to estimate the impact of forests on the climate system rely on often outdated estimates of albedo and do not consider the effects of management on forest albedo, even though these impacts can be significant and many forests are managed. We assembled estimates of albedo based on shortwave radiation data obtained at AmeriFlux sites to evaluate the estimates used in climate models. We found that albedos used for grassland and needle-leaf deciduous conifers were in need of revision. We also carried out measurements of albedo in managed conifer forest in central Maine, focusing on comparing shelterwood harvest forest with intact forest. We found that the more open canopy of a shelterwood had a slightly higher albedo than closed coniferous forest, especially in the winter. This means that in addition to potentially high rates of carbon sequestration, such shelterwood systems will lead to *reduced* climate warming compared to unmanaged forest but climate model simulations indicated change in surface temperatures to such slight changes in albedo.

Products:

Howland Forest albedo data resulting from this work were submitted to the AmeriFlux network database. The following publications resulted in whole or part from data obtained by the albedo instrumentation purchased with NSRC funding:

Hollinger, D.Y., S.V. Ollinger, A.D. Richardson, T.P. Meyers, D.B. Dail, M.E.

Martin, N.A. Scott, T.J. Arkebauer, D.D. Baldocchi, K.L. Clark, P.S. Curtis, K.J. Davis, A.R. Desai, D. Dragoni, M.L. Goulden, L. Gu, G.G. Katul, S.G. Pallardy, K.T. Paw U, H. Schmid, P.C. Stoy, A.E. Suyker, and S.B. Verma. 2010. Albedo estimates for land surface models and support for a new paradigm based on foliage nitrogen concentration. Global Change Biology 16:696-710.

Heilman, W.E., D.Y. Hollinger, X. Li, X. Bian, S. Zhong. 2010. Impact of Revised and Potential Future Albedo Estimates on CCSM3 Simulations of Growing-Season Surface Temperature Fields for North America. Atmospheric Science Letters. DOI: 10.1002/asl.301

Wang, Z., C.B. Schaaf, A.H. Strahler, M.J. Chopping, M.O. Román, Y. Shuai, C.E. Woodcock, D.Y. Hollinger, D.R. Fitzjarrald. 2014. Evaluation of MODIS albedo product (MCD43A) over grassland, agriculture and forest surface types during dormant and snow-covered periods. Remote Sensing of Environment 140:60–77.

Snowy forest – photo by Pam Wells

White tailed deer - Photo Pam Wells

Effectiveness of State Regulations to Protect Deer Wintering Habitats in Maine: Did the Designation of LURC-zoned Deeryards Achieve Desired Objectives during the Period 1975-2007?

***Principal Investigator**:* Daniel Harrison*, University of Maine*
***Co-PIs**:* Erin Simons-Legaard, Kasey Legaard, and Stephen Sader*, University of Maine*

We evaluated the effectiveness of zoning to protect wintering habitat for white-tailed deer (*Odocoileous virginianus*) across commercially managed forestlands in northern Maine. Prior to our study, approximately 190,000 acres (2-3% of land area) of deer wintering areas (DWAs) across 981 management units had been formally protected via zoning by Maine's Land Use Regulation Commission (LURC). Our primary goal was to evaluate the effectiveness of those protections by evaluating harvest history and habitat change within zoned DWAs from 1975 – 2007 and by quantifying the extent of change in extent and fragmentation of mature conifer forest habitat within a 1.25 mile radius buffer around zoned DWAs by applying a time-series of satellite imagery across a 4.1 million acres study area. We also evaluated the potential for expanded future zoning of remnant large patches of mature conifer forest. Thus, we quantified potential costs in terms of altered land value and value of wood potentially affected by increasing zoning to approximately 10% of the landscape, as has been proposed by Maine's wildlife management agency. Finally, we evaluated the value of zoned DWAs as sites for conservation of a broader array of forest vertebrate biodiversity.

Our results indicated that nearly all DWA's had harvesting activity within their boundaries, that 91% had at least 1 heavy harvest area, and that 23% of the mature forest area within DWA's was harvested from 1975 – 2007. More importantly, the extent of mature conifer forest habitat declined and the fragmentation of remnant patches of deer wintering habitat increased substantially in areas within 1.25 miles of the boundary of zoned DWAs from 1975-2007. Further, in 2007, < 1% of the landscape was in remnant patches of mature conifer forest that were > 250 acres in area, and virtually all remaining patches of mature conifer forest > 12.5 acres in area would need to be protected to achieve a goal of 10% of the landscape in conserved DWAs. We estimated that additional zoning of those areas could result in decreased land values of $160,000,000 and that the potential wood value on protected areas would total approximately $457,000,000 to landowners. Finally, we concluded that existing deer wintering areas were relatively ineffective in conserving a broader array of forest vertebrate biodiversity, suggesting that alterations in deer management objectives, as well as new approaches to forest landscape and biodiversity conservation are needed in the Northern Forest region.

Products:

- 1-hour seminar of results presented to Advisory Committee, Maine Cooperative Forestry Research Unit, 26 January 2011.
- Presentation of results to Chandler Woodcock, Commissioner, Maine Department of Inland Fisheries and Wildlife, February 2013.
- 1-hour seminar of results presented at University of Maine and attended by UMaine faculty and graduate students in Wildlife Ecology and Forest Resources, as well as by state and federal agency personnel, 15 October 2012.
- Final written report (in preparation) for Maine Cooperative Forestry Research Unit (publication and release by 31 December 2013) and will be made available in pdf format to managers, agencies, NGO's, and other interested parties.
- The Principal Investigator met with public affairs personnel at UMaineto plan for press release to occur simultaneous with release of CFRU report.
- A paper is in preparation for submission to a refereed journal (Forest Ecology and Management).

Role of Silvicultural Intensity and Species Composition Objectives on the Growth and Dynamics of Northeastern Forest Stands

***Principal Investigator**:* Andrew Nelson, *University of Maine*
***Co-PIs**:* Robert G. Wagner, Aaron R. Weiskittel, University of Maine; Michael R. Saunders*, Purdue University*

Early successional stands in Maine are often composed of a mixture of desirable and undesirable conifer and hardwood species. Stands are rarely managed resulting in forest productivity declines. The goal of this project was to examine the effects of factorial combinations of silvicultural intensity (thinning, thinning + enrichment planting, plantations) and species compositional objectives (conifer, mixedwood, and hardwood) on the growth and dynamics of early successional Acadian stands. First, aboveground component biomass were developed for juvenile trees in Maine and compared to existing models. The new models were then used to predict biomass across the treatment array to examine temporal trends in biomass. In the high intensity hybrid poplar plantations, four clones were planted. Three years following planting, hybrid poplar height and ground line diameter growth rates began to diverge among clones, and by six years, the *P. nigra* x *P. maximowiczii* (NM6) clone clearly outperformed three *P. deltoides* x *P. nigra* clones (D51, DN10 and DN70) both in pure stands and in mixtures with white spruce. In mixture, we found the yield of white spruce to decline as the yield of hybrid poplar increased. Overall, yields of the white spruce monocultures were comparable to those reported in eastern Canada, while the hybrid poplar biomass yields were substantially lower than those reported from studies on abandoned agricultural lands, likely due to the harsher soil conditions at our site. Seven years after treatment, yields of the two hardwood thinning and thinning+enrichment ranged from 43.4 to 56.6 Mg ha-1, which were similar to the 52.9 Mg ha-1 yield of the untreated control but with 17 and 46% lower densities, respectively. In the conifer release treatments, removal of hardwoods promoted conifer dominance and resulted in yields between 19.9 and 30.4 Mg ha-1 seven years after treatment. After seven years, yields of the mixedwood treatments were between 19% and 47% greater than the conifer release treatments due to the retention of thinned hardwood stems and represent stands that dominate much of the forestland in the region. Results from the experiment show that early successional Acadian stands can be shifted in different long-term developmental trajectories to meet a variety of landowner objectives with different intensities of silvicultural intensity.

Products:

Nelson, A.S., A.R. Weiskittel, and R.G. Wagner. 2014. Development of branch, crown, and vertical distribution leaf area models for contrasting hardwood species in Maine, USA. Trees 28(1): 17-30.

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

Nelson, A.S., M.R. Saunders, R.G. Wagner, 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(4): 519-534.

Pre-commercial thinning crew, Milford, Maine - photo by Pam Wells

Taxation and Sustainable Management in the Northern Forest

Principal Investigator: David Newman*, SUNY ESF*
Co-PI: Bob Malmsheimer*, SUNY ESF*

Canham (1992) performed the most recent comprehensive analysis of the tax situation in the Northern Forest but substantial changes have occurred in the region since then. Forest industry has been divesting its lands to individuals and pension funds, property values have increased substantially, and rising property taxes have made sustainable forest management problematic. The role of state taxes, in particular, is of substantial concern because the different ways in which timber and land are taxed between the four states can have substantial competitive and sustainability impacts for the forest sector as a whole. The objective of this study was to analyze the total tax burden associated with federal and state taxes on timberland owners in the four Northern Forest states. We reviewed existing forest taxation policies and current issues regarding tax impacts on forest management in the four states. We compared changes in Land Expectation Value from all taxes affecting forested land, evaluating the taxation of both hardwood and softwood forest types. An important outcome of this research was a clearer understanding of the role of tax policy in the Northern Forest states and the implication that it has for sustainable forest management in the region.

Products

Presentations

Newman, D.H., B. Malmsheimer, and J. Haas. 2010. Taxation and Sustainable Management in the Northern Forest. NY SAF Meeting. Syracuse, NY, 1/28/10; Also NE SAF Meeting, Durham, NH 3/9/2010

Newman, D.H., J. Haas, and N. Malmsheimer. 2012. The Impact of Taxation on Land Expectation Value (LEV) and Sustainable Forest Management in the Northern Forest States. NY SAF Meeting. Syracuse, NY, 1/27/12

Newman, D.H. and N. Malmsheimer. 2013. Taxes in the Northern Forest 20 Years After the Northern Forest Lands Study. NY/NE SAF Meeting. Saratoga Springs, NY, 1/31/13

Newman, D.H. 2013. Property Tax Issues in NY: The Way Forward? ESFPA Annual Meeting, Syracuse, NY, 9/26/13

Graduate Students

Jonathon Haas. 2011. The Impact of Taxation on Land Expectation Value (LEV) and Sustainable Forest Management in the Northern Forest States. Unpublished M.S. Thesis, SUNY ESF.

Manuscripts

Newman, D.H., J.E. Wagner, J. Haas, and R.W. Malmsheimer. The Impact of Forest Taxation on Working Forests in the Northern Forest States. (Submitted to the Northern Journal of Applied Forestry)

Response of Tree Regeneration to Commercial Thinning in Spruce-Fir Forests of the Northeast

Principal Investigator: Matthew G. Olson, *Missouri Dept. of Conservation*
Co-PIs: Spencer R. Meyer, Robert G. Wagner, Robert S. Seymour, *University of Maine*

Balsam fir stand - photo by Pam Wells

The spruce-fir forest type is important to the economy of the northeastern United States. This northern conifer forest type supports multiple wood products industries, yet also provides numerous recreational opportunities for residents and non-residents alike. Of the northeastern US forest, the spruce-fir type is the most intensively managed.

Owners of northeastern spruce-fir forests interested in timber production are increasingly applying commercial thinning on their lands. Commercial thinning is traditionally used to enhance tree growth by reducing crowding, while harvesting merchantable trees for forest products. Enhanced growth of the remaining trees is driven by increases in the availability of plant resources, such as light, water, and nutrients. This transient increase in plant resources may also stimulate the establishment of new trees, a process called regeneration.

Although triggering regeneration is not traditionally an objective of thinning, understanding what responses to anticipate can help forest managers plan for future operations that renew their forests after final harvest. This knowledge is particularly valuable when sustainably managing forests dependent on natural regeneration, such as northeastern spruce-fir forests.

We used two long-term commercial thinning experiments in spruce-fir forests of Maine maintained by the University of Maine's Cooperative Forestry Research Unit to test two hypotheses: (1) commercial thinning increases the abundance of tree regeneration and (2) tree regeneration abundance increases with increasing thinning intensity. A decade after thinning, abundance of desirable conifer regeneration was 10-times greater in thinned than unthinned stands. Small conifer abundance was highest in lower intensity thinning treatments, while the abundances of larger conifer regeneration increased proportionally with thinning intensity. The abundances of broadleaf species regeneration generally increased with thinning intensity. Therefore, in addition to providing higher individual-tree growth and merchantable yield, commercial thinning in northeastern spruce-fir stands also increases regeneration abundance.

This response to commercial thinning has implications for the sustainability of managed northeastern spruce-fir, since commercial thinning may simultaneously improve tree growth and accumulate desirable conifer regeneration. In turn, this could shorten rotation length by reducing the time needed to develop acceptable regeneration abundance under more traditional methods for regenerating spruce-fir forests.

Products

Peer-reviewed publications

Olson, M.G., S.R. Meyer, R.G. Wagner, and R.S. Seymour. 2014. Commercial thinning stimulates natural regeneration in spruce-fir stands. Canadian Journal of Forest Research. 44(3): 173-181. doi:10.1139/cjfr-2013-0227

Other publications

Olson, M.G., S.R. Meyer, R.G. Wagner, and R.S. Seymour. 2013. In: Cooperative Forestry Research Unit: 2012 Annual Report, B.E. Roth (Ed.), 95 p. Response of tree regeneration to commercial thinning in spruce-fir stands of Maine: first decade results from the Commercial Thinning Research Network. p. 19-23.

Olson, M.G., S.R. Meyer, R.G. Wagner, and R.S. Seymour. 2012. In: Cooperative Forestry Research Unit: 2011 Annual Report, B.E. Roth (Ed.), 111 p. Response of tree regeneration to commercial thinning in spruce-fir stands of Maine: first decade results from the Commercial Thinning Research Network. p. 20-24.

Conference Presentations

Olson, M.G., S.R. Meyer, R.G. Wagner, and R.S. Seymour. Tree regeneration ten years after commercial thinning in spruce-fir stands of the northeastern US. 2013 SAF National Convention, Charleston, South Carolina, October 23-27, 2013.

S.R. Meyer, Olson, M.G., R.G. Wagner, and R.S. 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 ECANUSA Forest Science Conference, Durham, New Hampshire, October 2012.

Forest Regeneration Differences between Whole-Tree and Conventional Harvesting Methods in Northern Hardwoods: A Concern for Sustainable Bio-fuel Production?

Principal Investigator: Theodore E. Howard*, University of New Hampshire*
Co-PI: Gabriel Roxby*, Society for the Protection of New Hampshire Forests*

Whole tree harvesting (WTH) is increasingly used to supply wood chips for biomass energy production. In a typical whole tree harvesting operation the trunk of the tree is used for traditional products (lumber, construction materials, etc.); branches and fine twigs are sold to a biomass energy plant. Conventional harvesting, in contrast, leaves branches and twigs on site to decompose. There has been concerns that additional removal of nutrient-rich branches and twigs by WTH might impair forest productivity – leaving a forest that regenerates trees that are slower growing and of lesser quality.

To assess effects of harvest treatment on New England's northern hardwood forests, we conducted a regeneration survey of 29 small clearcuts in central New Hampshire and western Maine. We measured 14 whole-tree harvested and 15 conventionally harvested (CH) sites and compared the productivity of the 10–14 year old regeneration. Conventionally harvested sites were located on public lands within the White Mountain National Forest (WMNF). Out of concern for site degradation, WTH is not currently practiced on the WMNF, so WTH sites were located on private lands. Due to the difficulty in finding sites that met our criteria, WTH sites were heavily clustered in west central New Hampshire.

Within each plot at each site, the height, diameter at breast height (DBH) and species of all trees >2 m in height within a 1 m radius were recorded. The slope and aspect of each plot were measured. Soil parent material was of glacial till origin for all sites, but was visually classified as either well-drained or moderately well-drained. The position and height of uncut edge trees surrounding the patch cut were recorded. These edge trees were used to calculate the patch cut size and to develop a spatial solar radiation model to determine the amount of sunlight each sample plot received during the growing season (Figure 18). Biomass was calculated using species-specific regression equations based on measured diameter.

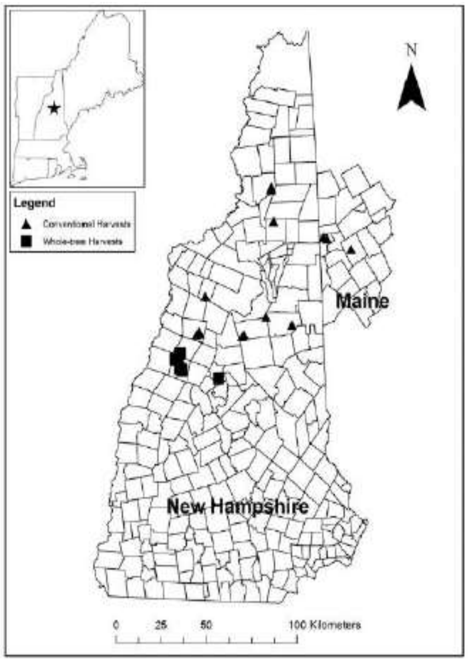


Figure 18 Locations of 14 whole-tree harvested (squares) and 25 conventionally harvested (triangles) study sites in New Hampshire and western Maine.

No significant difference was observed in height, diameter or calculated biomass of stems >2 m in height between WTH and CH treatments. Our study found no evidence of productivity decrease 10-14 years following single whole-tree harvesting in comparison with conventional bole-only methods. Mixed effects models and quantile regressions both showed that choice of harvest treatment had no significant effect on biomass, height or diameter of regenerating stems. Our results are limited by several factors: the extent of moose browsing, the restriction of WTH to private forest lands, as well as the development stage of the measured stands. Further, our analysis examined only a limited set of timber productivity measures and did not address broader questions of ecological productivity.

Products

Peer Reviewed

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.

Other

Roxby, G. and T. Howard. 2012. Whole Tree Conventional Harvesting: Assessing Productivity Differences. 2012 ECANUSA Forest Science Conference. Durham, NH. Nov 1-3.

Roxby, Gabriel. 2012. Effects of Whole-Tree Harvesting on Site Productivity and Species Composition in Northern Hardwood Forests. M.S. Thesis. University of New Hampshire. 112 pages.

Roxby, Gabriel. 2012. Effect of Whole Tree Harvesting on Site Productivity. Presentation at Biomass Harvesting -What is left behind? NHTOA and UNH Cooperative Extension Workshop. Bridgewater, NH. July 26, 2012.

Roxby, Gabriel. 2011. Evaluating the Sustainability of Whole-Tree Harvesting. University of New Hampshire Graduate Research Conference. April, 2011. Durham, NH.

Evaluating the Interacting Effects of Forest Management Practices and Periodic Spruce Budworm Infestation on Broad-scale, Long-term Forest Productivity

Principal Investigator*:* Kasey Legaard*, University of Maine*
Co-PIs*:* Erin Simons-Legard, Jeremy Wilson, & Steve Sader*, University of Maine*

The sustainable management of forests requires a clear understanding of the cumulative effects of anthropogenic and natural disturbance over large spatial scales and long time horizons. In the Northern Forest, timber harvesting is the primary disturbance agent, but insect outbreaks can be an additional, critical agent of disturbance that influences and interacts with forest management. Due to host-specificity, the disturbance dynamics of insect outbreaks are closely coupled to the distribution of their host species; thus, changes in forest composition and age resulting from timber harvesting can influence the development, duration, and intensity of an outbreak (e.g., Radeloffet al., 2000). In addition to this indirect interaction, the decisions of land owners to salvage harvest during an outbreak to capture value that would otherwise be lost to insect-induced mortality (Foster and Orwig, 2006) can drastically alter forest structure and have lasting effects on the vulnerability of a landscape to future outbreaks.

We used a forest landscape model, LANDIS-II (LANDscapeDIsturbanceand Succession), to simulate the coupled dynamics of forest management and periodic outbreaks of the eastern spruce budworm [*Choristoneurafumiferana* (Clem.)] across a 10 million acre study area in northern Maine. This native pest of the northeastern U.S. and eastern Canada has historically infested these regions every 30 to 50 years, causing widespread defoliation, growth reduction, and mortality of balsam fir (*Abiesbalsamea*) and spruce (*Piceaspp.*) trees (MacLean, 1980, Irland et al., 1988). Apparent increases in outbreak extent, synchronicity, and severity throughout the 20th century have fueled decades of debate concerning the influence of forest management practices on budworm disturbance dynamics, and we designed scenarios to provide a better understanding of how harvesting, salvage, and budworm outbreaks interact and influence forest dynamics and wood supply.

Our projections suggest that the spread and increasing dominance of balsam fir, the primary host species for budworm, will drive changes in landscape vulnerability to infestation. Many areas in northern Maine that did not support balsam fir and spruce species in 2010 may transition to a more mixed composition with a significant host component by 2050. Following a spruce budworm outbreak, the combination of budworm-induced mortality and salvage will cause a short-term 15-30% (depending on timing and outbreak severity) decline in spruce-fir biomass. Spruce-fir forest will recover in many disturbed or salvaged areas but not all as successional dynamics drive forest type conversion in other areas.

Products

Manuscripts in preparation

Calibration of LANDIS-II to Acadian forest species and dynamics (anticipated submission 4/2014).

Evaluating interactions between policy and management on resource sustainability (anticipated submission 8/2014)

Presentations

Simons-Legaard, E. M., K. Legaard, A. Weiskittel, and S. Sader. 2013. Evaluating the interacting effects of forest management and spruce budworm outbreaks on broad-scale, long-term forest conditions in the Northern Forest of the northeastern U.S. Oral presentation at the Annual Meeting of the Ecological Society of America, Minneapolis, Minnesota.

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. Oral presentation at the 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. Poster presented at the Eastern CANUSA Forest Science Conference, Durham, New Hampshire.

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 borad-scale sustainability of forest resources: wood supply, carbon, and wildlife habitat. Poster presented at the Eastern CANUSA Forest Science Conference, Durham, New Hampshire.

Grants resulting in part from the success of this project

NSF Coupled-Natural Human Systems, 2013: When natural disturbance meets land use change: an analysis of disturbance interactions and ecosystem resilience in the Northern Forest of New England. Lead PI E. Simons-Legaard.

NASA/USDA National Institute of Food and Agriculture (NIFA) Carbon Cycle Science, 2010: Carbon dynamics and forest management: A retrospective analysis and projection of the potential effects of land use, climate change, and natural disturbance in northeastern forests. Lead PI A. Weiskittel.

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

Principal Investigator: Jessica E. Leahy, *University of Maine*
Co-PI: Aaron Weiskittel, *University of Maine*

Predicting and understanding timber supply is one central component to the viability of the bioenergy industry. This study seeks to understand the knowledge, attitudes, risk perception, and willingness to harvest timber for bioenergy markets. Thirty-two interviews were conducted with private woodland owners (non-industrial, family owners) in Maine who had previously harvested timber, had never harvested timber, and had harvested timber for woody biomass markets to explore these concepts in depth. Results indicate that private woodland owners have little knowledge of biomass harvesting, but a desire to learn more. Attitudes toward biomass harvesting were mixed, with negative attitudes about nutrient removal, poor economics, and biomass as a poor end-use for wood products. Positive attitudes towards biomass pertained to fossil fuel replacement, a use for low-quality wood, and strengthening Maine's forest economy. Some owners expressed a willingness to supply timber for biomass, but not all landowners that had harvested for bioenergy markets would do so again. Many landowners felt that biomass was not economically feasible and felt the risk of damaging forest ecosystems did not outweigh potential benefits in having a market for low-value wood materials. It did not matter to landowners where the materials ended up, what they were used for (electricity vs. conversion into a mobile fuel source), or what was done with the byproducts of wood burning. Rather, once the wood leaves their property, they don't dwell on the specifics other than hoping it goes to the best possible end use. These results help provide insight to available timber supply for the bioenergy industry and provide an assessment of landowner awareness of timber harvesting options. The Northern Forest region is an ideal place for locally-sourced wood-based heat, due to an abundance of wood and a rural population that could benefit from reduced energy costs. However, the vast majority of forests are owned by private woodland owners, so timber supply for wood-based energy production could be severely constrained by the motivations and willingness to harvest by private woodland owners. Better outreach, information, and market conditions are important to facilitate biomass harvesting on private woodlands in the Northern Forest.

Products

Peer-reviewed Publications

Silver, E.J., Leahy, J.E., Weiskittel, A., Noblet, C.L., Kittredge, D.B. 2014. Maine woodland owner perceptions of biomass harvesting and bioenergy. In preparation, Expected finish date July 1st, 2014.

Silver, E.J., Leahy, J.E., Weiskittel, A., Noblet, C.L., Kittredge, D.B. 2014. An evidence-based review of timber harvesting among private woodland owners. Expected finish date July 1st 2014.

Silver, E.J., Leahy, J.E., Kittredge, D.B., Noblet, C.L. 2014.Psychological distance of timber harvesting for private woodland owners. Expected finish date August 1, 2014.

Silver, E.J., Leahy, J.E., Weiskittel, A., Noblet, C.L. 2014. Risk perception of harvesting timber for biomass production. In preparation, Expected finish date September 1st, 2014.

Silver, E.J., Leahy, J.E., Weiskittel, A., Hiebeler, D. 2014. An agent-based predictive model of private woodland owner communication and sustainable harvesting decisions. Expected finish date December 1, 2014.

Other Publications

Silver, E.J., Leahy, J.E. 2014. Social availability of biomass in Maine: Perspectives of private woodland owners. A report written for the Sustainable Energies Pathways grant team and the Maine Forest Service

Conference Presentations

"Risk perception and relevance of timber harvesting for private woodland owners: A qualitative examination.", International Symposium on Society and Resource Management, Hannover, Germany, 2014.

"Risk perception and relevance of timber harvesting for bioenergy production: A qualitative examination of private woodland owners", Maine Water and Sustainability Conference, 2014

"Risk perception of timber harvesting for bioenergy production: A qualitative examination of private woodland owners", New England Society of American Foresters Annual Meeting, 2014

"Private Woodland Owner Timber Harvesting Behavior: The difference between attitudes, intentions, and behavior", Society of American Foresters National Convention, 2013

Websites/Databases

Interview data posted to the University of Maine Dataverse server.

Graduate Student Grants

Sustainability Solutions Initiative Travel Grant, $827, to Emily Silver

Graduate Student Government Travel Grant, $416, to Emily Silver

Understanding Individual & Community Level Conservation Behavior Adoption of Sustainable Forest-Based Heating Alternatives in Rural New England, USDA NIFA AFRI, $499,000 [pending]

NSRC THEME 3 ANNUAL PROGRESS REPORTS

Comment [MF1]: Figures need consecutive numbering here to end

Silvicultural Effects on Environmental Conditions and Resulting Aboveground Productivity and Carbon Sequestration of Northeastern Mixedwood Forests

Lead Principal Investigator*:* Andrew S. Nelson*, University of Maine*
Co-Principal Investigators*:* Robert G. Wagner, Michael E. Day, and Ivan J. Fernandez, *University of Maine*

Summary of Progress: FY 2013 – 2014

During the past year, funds for this project have been used to finalize field work and write manuscripts related to the project. One manuscript has been published. This study developed models of total leaf area production and vertical leaf area distribution within individual tree crown across a range of tree species. Two manuscripts are currently in review: (1) comparing the effects of light capture on δ13C and aboveground biomass growth of juvenile white spruce in plantations and natural stands, and (2) temporal changes in stand leaf area index and vertical canopy leaf area index following silvicultural treatments designed to shift stands in different long-term developmental trajectories.

Remaining funds for this project will be collect additional field data from the SIComp experiment on the Penobscot Experimental Forest in eastern Maine. These data will provide ten years of measurements of tree development following treatment with factorial combinations of silvicultural intensity and species compositional objectives. Long-term measurements on tree growth and survival will be used to develop an individual tree growth and yield model for juvenile tree in response to silvicultural treatment. This model will be integrated with larger growth and yield modeling efforts in the Acadian forest region.

Major findings from the three investigations are summarized below.

Individual tree leaf area production and vertical leaf area distribution

The majority of leaf area models in the literature are focused on conifer species, which have substantially different crown forms than hardwood species. Therefore, the goal of this investigation was to develop branch, crown, and vertical leaf area distribution models for various hardwood species that accounted for their greater crown complexity. A nonlinear model including branch diameter, branch tip height and height to the start of the foliage was the best fit for branch leaf area. Branch leaf area ranged from 0.05 m2 to 0.37 m2 for *Populus grandidentata* and *Betula populifolia* for an averaged sized branch, respectively. The best fit model for crown leaf area was a nonlinear form accounting for stem diameter and crown length. Crown leaf area ranged from 3.26 m2 to 9.85 m2 for *Populus tremuloides* and *Betula populifolia* for an averaged sized tree, respectively. Vertical leaf area distribution was best fit by a right-truncated Weibull distribution and showed a peak in the middle third of the crown for most of species (Figure 19). In addition, leaf area production varied among four hybrid poplar clones in plantations, suggesting a strong genetic control over crown form. Overall, leaf area varied among species at all levels of investigation, suggesting that coexistence of hardwood saplings in this investigation was strongly influenced both by inherent species-specific leaf area production and vertical distribution.

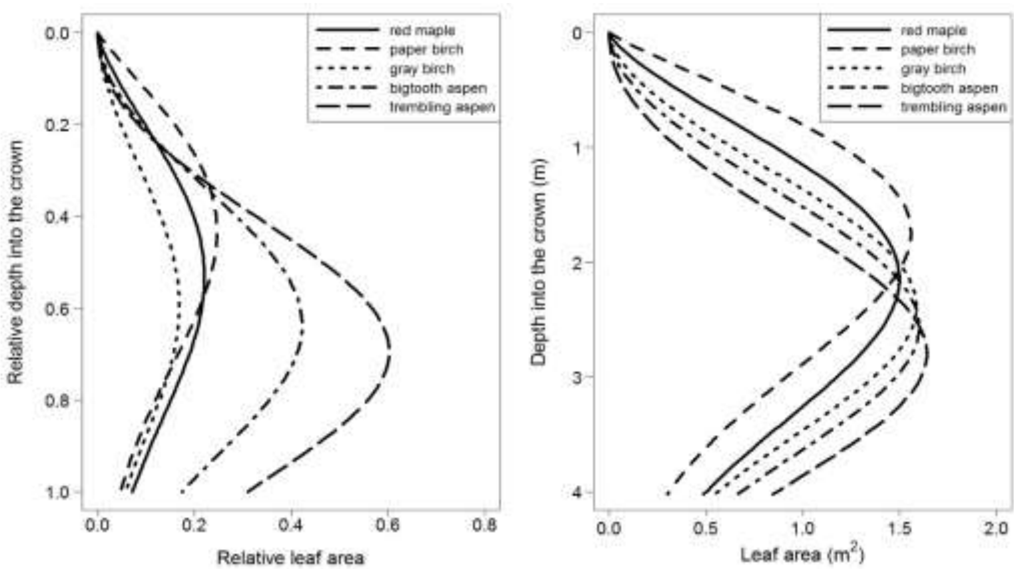


Figure 19 . Relative absolute vertical leaf area for five naturally regenerated hardwood species fit with the right-truncated Weibull distribution. The Weibull shape and scale parameters used to display curves were mean values from all trees within a species.

White spruce light capture, foliar δ13C, and aboveground biomass growth

Aboveground net biomass growth (AG) of trees is influenced primarily by resource availability, resource capture, and conversion efficiency of captured resources into biomass. These tree-level mechanisms are underlain by physiological processes that influence responses to heterogeneous growing conditions. In this investigation, AG, light-use efficiency (LUE; AG/absorbed photosynthetically active radiation (APAR)), and foliar stable carbon isotope composition (δ13C) of white spruce trees were compared between enrichment planting in naturally-regenerated stands and plantations. AG was linearly correlated with APAR, but APAR accounted for only 50.8% of the variation in AG possibly due to unaccounted factors such as water and nutrient availability (Figure 20). LUE was 80.0% greater, on average, in natural stands, but LUE differed between the smallest tree and largest tree by only 1.4%, and between the lowest level of an inter-tree competition index and the highest level of the competition index by only 5.4%. The minimal differences in white spruce LUE in both treatments was likely because stands had yet to reach crown closure where density-related competition often results in differentiation in resource-use efficiency where dominant trees become more efficient due to greater capture of above- and below-ground resources. Comparatively, δ13C increased with tree size by 1.5‰, and declined by 1.7‰ with greater competition in the natural stands possibly due to differences in interspecific light capture. δ13C was not correlated with AG, LUE or LAE, likely due to photosynthate allocation to other sinks besides AG, including root growth, storage, and respiration. Overall, light absorption of these juvenile white spruce trees was a major factor driving AG, suggesting that within natural stands, where crown closure will occur sooner than within plantations, AG and LUE of white spruce trees will likely decline earlier and result in lower future productivity.

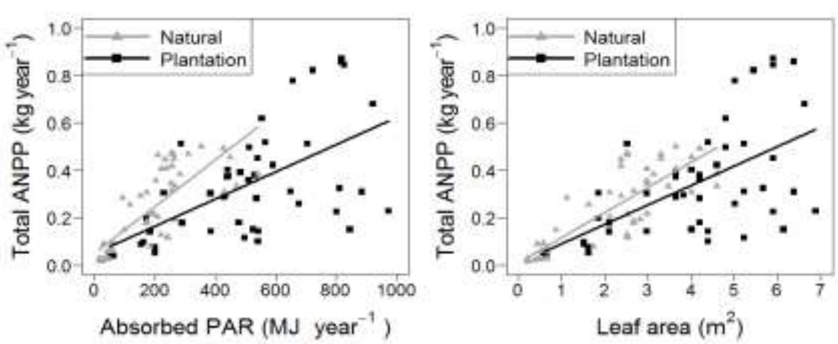


Figure 20 Relationship between absorbed light (PAR) and total aboveground biomass growth, and leaf area and biomass growth of white spruce trees in plantations and in natural stands

Temporal changes in leaf area index and vertical distribution of leaf area index in response to silvicultural treatment

Leaf area index (LAI) affects rates of forest-atmosphere fluxes and light interception, and thus, influences potential productivity. Disturbances, such as intermediate silvicultural treatments, affect LAI partitioning among species of different shade tolerance in natural stands due to changes in composition and structure. We examined the influence of thinning intensity (one-time thinning [thin], thinning + enrichment planting [thin+enrich]) and compositional objective (conifer, hardwood, mixedwood) on total stand LAI and its vertical distribution by different shade tolerance groups over a seven year period in Maine, USA. Hardwood LAI increased by 242% and 318% in the hardwood-thin and -thin+enrich treatment, respectively, compared to only a 123% increase in the control. Thinning likely increased resource availability for upper stratum shade intolerant hardwood trees, while increasing light penetration through the canopy for capture by midstory shade tolerant hardwoods. Conifer treatments substantially reduced overtopping shade intolerant hardwood LAI, facilitating an increase in conifer LAI by 281% and 378% in the thin and thin+enrich treatments, respectively. Hardwood and mixedwood treatments had a greater effect on the height above the crown base where LAI peaked than the amount of LAI at that peak (Figure 21). The converse was true in the conifer treatments, likely due to slower height growth following release from hardwood species and stacking of foliage within the middle portion of the canopy. With effective strategies to thin overstory trees and release overtopped trees, total LAI and the distribution of LAI through the canopy can be shifted to favor resource capture by desired species and alter developmental trajectories.

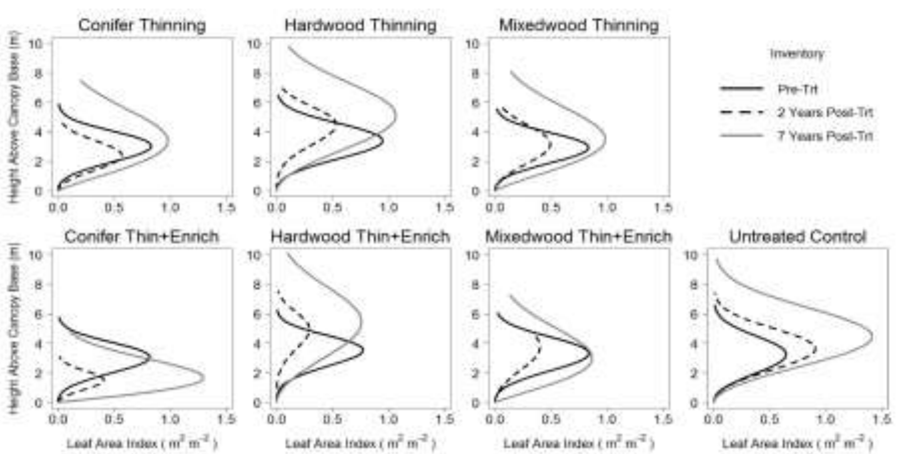


Figure 21 Vertical leaf area index distribution through the entire canopy in stands shifted in different developmental trajectories with different intensities of silvicultural treatments. Data is shown prior to treatment (Pre-trt), 2 and 7 years after treatment.

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

Principal Investigator*:* Ronald S. Zalesny Jr.*, U.S. Forest Service, Northern Research Station*

Co-Principal Investigators: Steve Colombo, Pengxin Lu, and Bill Parker*, Ontario Forest Research Institute;* John Brissette*, U.S. Forest Service, Northern Research Station*

Summary of Progress: FY 2013-2014

Diameter and growth increment data for Wabeno, Manistique, Pine River, and Newaygo trees ranging from 40 to 49 years of age were analyzed for an off-shoot study assessing biomass and carbon sequestration potential of white pine versus short rotation poplars in the Lake States. Assistance was provided from scientists at Iowa State University (Drs. Richard B. Hall and William L. Headlee). Les Groom and his team are conducting the x-ray densitometry work. Conference calls were held to discuss plans for reporting and manuscript writing.

As in previous years, 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.

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. To this end, a research joint venture agreement was established with Dr. Sophan Chin of Michigan State University who will lead efforts for the production of the following papers:

Paper #1: Growth response functions of provenance trials under past and future climate

Paper #2: Dendroclimatic analysis of white pine natural forests under past and future climate

Paper #3: Dendroclimatic analysis of white pine provenance trials under past and future climate

Priorities for Next Quarter

Our main priority for this reporting period is to analyze and summarize data, and then prepare the final report and first manuscript outline above 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; and use validated models from (4) and future climate projections to predict radial and stem growth response of white pine in the northeastern U.S., and contribute to provisional seed transfer recommendations for assisted migration of white pine seed sources to help adapt northern forests to future climate.

Predicting Effects of Even- and Uneven-aged Silviculture on Commodity Production, Carbon Sequestration, and Wildlife Habitat Characteristics in Northern Hardwoods

Co-Principal Investigators*:* Ralph D. Nyland, Eddie Bevilacqua, and Dian H. Kiernan*,*
SUNY College of Environmental Science and Forestry Syracuse

Summary of Progress: FY 2013-2014

Research and a resulting thesis into diameter growth and mortality of northern hardwoods in even-aged stands was completed by David A. Schmidt (March 2014). A manuscript targeted at *Forest Science* is currently in preparation. It describes 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 have been integrated into the even-aged northern hardwood stand simulator currently in preparation as part of the project.

A manuscript related to thesis research by Lindsay Nystrom is ready for submission to *Forest Science* during July 2014. 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. They show that regeneration of other species will fail in stand having important amounts of understory beech saplings. Where understory beech has low importance, the functions show an annual increase of ingrowth to the 1-inch class through 8-10 years, and a reduction thereafter. Levels of ingrowth also vary with residual stand density

Work to integrate the ingrowth functions for the uneven-aged stand simulator, and growth and mortality functions for the one dealing with even-aged stands, will be completed during July 2014. We also have work underway to add interface modules so users can input data from stand inventory files, or stand tables, into the simulators as starting conditions for a simulation run.

As part of the project we sampled or otherwise assembled data from 46 stands to describe starting conditions for future simulation runs. These articulate a range of structures and densities in even-aged northern hardwoods at intermediate stages of development, and appropriate for a cultural treatment. Some of the stands had been permanently documented in the past, providing us with remeasurement data to use in comparing simulated outcomes with actual change in stand conditions.

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

Co-Principal Investigators: A. R. Weiskittel, J. C. Brissette, I. J. Fernandez, L. S. Kenefic, R. K. Kolka, and L. Rustad

Summary of Progress: FY 2013-2014

In August - October 2013, we finished collecting mineral soil samples within treatments and processed these samples in the laboratory for TC, TN, pH, CEC, and nutrient analysis. At each soil core location, we also collected additional O horizon samples for chemical analyses. Processing of the samples was completed in March 2014. This work will allow us to estimate soil C content within treatments on the PEF.

In July - August 2013, we measured tree heights on a subset of plots within treatments to compare methods for estimating bole biomass. The height data were also used to validate height-diameter equations developed for the Acadian Forest (Saunders and Wagner 2008; Rijal et al. 2012), and to select an appropriate height-diameter equation for use in this study. This work will allow us to predict the volume of snags with greater precision.

In July - August 2013, we also installed transects on the same subset of plots, and O horizon depth measurements and herbaceous cover estimates were recorded along transects. Our goal is to use these data to derive a more precise estimate of O horizon and herbaceous biomass and C content. We will also evaluate the influence of factors on O horizon depth and herbaceous cover by and within treatments.

The PhD student working on this project has completed the comprehensive exams and is working on analyzing these data and writing manuscripts. This fall, results will be presented at the International Union of Forest Research Organizations (IUFRO) World Congress, and the Society of American Foresters (SAF) - Canadian Institute of Forestry/l'Institut forestier du Canada (CIF/IFC) joint convention.

References

Rijal, B., A. R. Weiskittel, and J. A. Kershaw. 2012. Development of regional height to diameter equations for 15 tree species in the North American Acadian Region. *Forestry* 85(3): 379-389.

Saunders, M. R., and R. G. Wagner. 2008. Height-diameter models with random coefficients and site variables for tree species of Central Maine. *Ann. For. Sci.* 65(2).

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

Principal Investigator: Mohammad M. Bataineh*, University of Maine*
Co-Principal Investigators: Aaron Weiskittel*, University of Maine;* Laura Kenefic*, U.S. Forest Service, Northern Research Station;* Ben Rice*, University of Maine;* Robert Seymour*, University of Maine*

Summary of Progress: FY 2013-2014

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.

The project has been recently extended for one additional year (until 6/30/2015) beyond project duration because of delays in compiling available datasets and acquiring Forest Inventory and Analysis data. In addition, the principal investigator (Mohammad Bataineh) had accepted a new position at the Center for Research on Sustainable Forests with additional responsibilities that required greater time allocation away from this project. The aforementioned principal investigator status has changed again by accepting a position at the University of Arkansas at Monticello starting August 1, 2014. This progress report is in part a notification of this change in status and a plan for the continuation of this project by naming Co-PI Aaron Weiskittel as the new project PI.

During the second year of project duration we have: (1) completed compiling data and processing seedling cross-sections and hemispherical photos; (2) developed hierarchical generalized regression models and presented regional analysis of data collected from the Non-Selective Partial Harvesting Study in a Ph.D. Dissertation (CO-PI: Ben Rice) chapter; and (3) presented results regarding the effect of overstory conditions and other site factors on natural regeneration at the Society of American Foresters 2013 National Convention in South Carolina.

The project next key milestone is completing additional analysis using Forest Inventory and Analysis data and/or previously compiled UMaine data on partial harvesting. We opted to modify our previous plan, of extending the scope of this project to include the calibration of an expert regeneration model (REGEN), in favor of the evaluation of long-term regeneration response following silvicultural treatments at the Penobscot

Experimental Forest. This evaluation will include the use of complexity measures as predictors of effect on seedlings height distribution and will be more informative to future calibration efforts of REGEN as well as management strategies.

Accomplishments

During the second year of the project duration we have accomplished the following:

1. Data compilation and sample processing: data from the three studies were compiled, seedling cross-sections and hemispherical photos were processed.

2. Data analysis: data collected from the Non-Selective Partial Harvesting Study were analyzed and presented as part of a Ph.D. dissertation by Co-PI: Ben Rice.

3. Reporting and outreach: the effects of silviculture and site factors on natural regeneration were reported in a publication in Forest Ecology and Management and in poster format at the Society of American Foresters National convention, Silviculture Matters, South Carolina.

<u>Journal Publications</u>

Bataineh, M., Kenefic, L., Weiskittel, A., Wagner, R., and Brissette, J. 2013. Influence of partial harvesting and site factors on the abundance and composition of natural regeneration in the Acadian Forest of Maine, USA. Forest Ecology and Management 306:96-106.

<u>Theses and student reports</u>

Rice, B. in progress. Natural regeneration abundance, composition, and structure in partially harvested stands of the Acadian Forest Region. Ph.D. Dissertation chapter, University of Maine.

<u>Presentations, Posters, Field Tours and Workshops</u>

Bataineh, M., Kenefic, L., Weiskittel, A., Wagner, R., and Brissette, J. 2012. Influence of partial harvesting and site factors on the abundance and composition of natural regeneration in the Acadian Forest of Maine, USA. Silviculture Matters, Society of American Foresters National Convention, North Charleston, South Carolina., October 23-27, 2013. – Poster Presentation

Project milestones and future plans

The project next key milestone is completing additional analysis using Forest Inventory and Analysis data and/or previously compiled UMaine data on partial harvesting. We opted to modify our previous plan, of extending the scope of this project to include the calibration of an expert regeneration model (REGEN), in favor of the evaluation of long-term regeneration response following silvicultural treatments at the Penobscot Experimental Forest. This evaluation will include the use of complexity measures as predictors of effect on seedlings height distribution and will be more informative to future calibration efforts of REGEN as well as management strategies.

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

Principal Investigator: Spencer R. Meyer*, University of Maine*
Co-Principal Investigators: Michelle L. Johnson, Aaron Weiskittel, Robert J. Lilieholm, Jeremy Wilson, Christopher S. Cronan*, University of Maine; Susan Stein, Private Forest Lands Studies Coordinator, USDA Forest Service*

Summary of Progress: FY 2013-2014

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 an assessment of the wood supply that could be affected by future development patterns.

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.

Land Use Models

In November, 2012 we convened a group of stakeholders representing the economic development and forestry sectors. We used this group to refine and validate Bayesian network land use models developed for two study watersheds in Maine. We also identified plausible future scenarios based on stakeholder input. The final land use models from that process were presented in our 2013 progress report to NSRC. The final resulting suitability maps—for not only forestry and development, but also for conservation and agriculture—are shown in Figure 22.

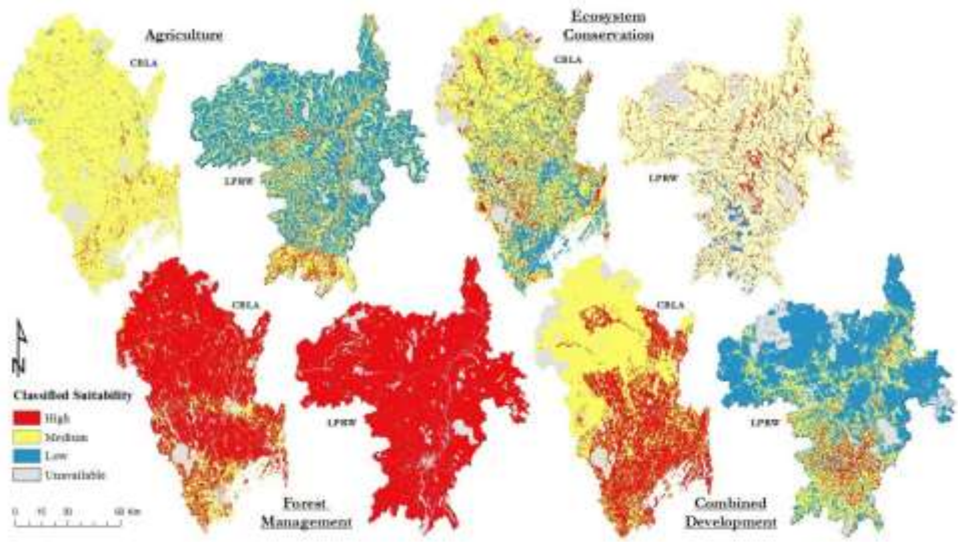


Figure 22 Complete suitability maps for both watersheds

Alternative Futures Models

We then developed a cellular automata land use model, Land Use Spatial Allocation Model (LUSAM), which integrates multiple land uses, models land use transitions at a patch resolution, and incorporates stakeholder-derived suitability data from the aforementioned Bayesian network models. Constructed in NetLogo, LUSAM uses flexible model parameters to vary the spatial allocation of three land uses across scenarios: development, agriculture, and conservation. These model parameters alter the size, shape, and distribution of new land use patches. Based on stakeholder input, we constructed a series of land use change scenarios for the Lower Penobscot River Watershed (LPRW) in central Maine and the Casco Bay/ Lower Androscoggin Watershed (CBLA) (Figure 23). We incorporated these scenarios into LUSAM to develop spatial representations of five land use change scenarios that could occur by the year 2036 (Figure 24). Our five scenarios varied according to conservation network location, development distribution, and area in agriculture, demonstrating the implications of land use changes on forest fragmentation and conserved lands.

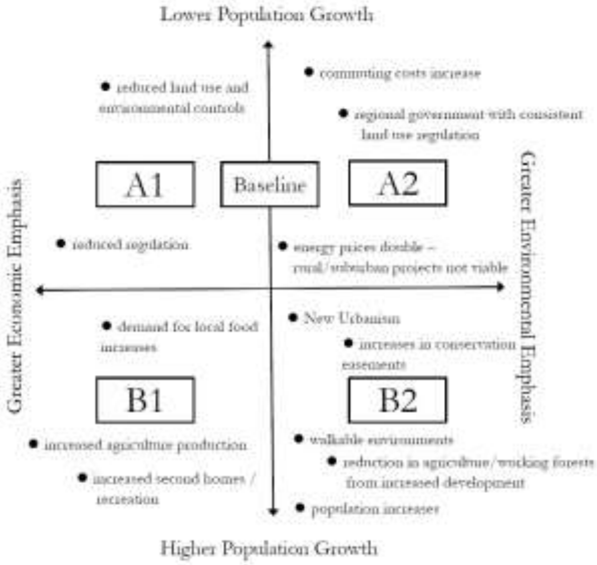


Figure 23 . Scenario matrix for future development, forestry, conservation, and agriculture trends, based on input by stakeholders.

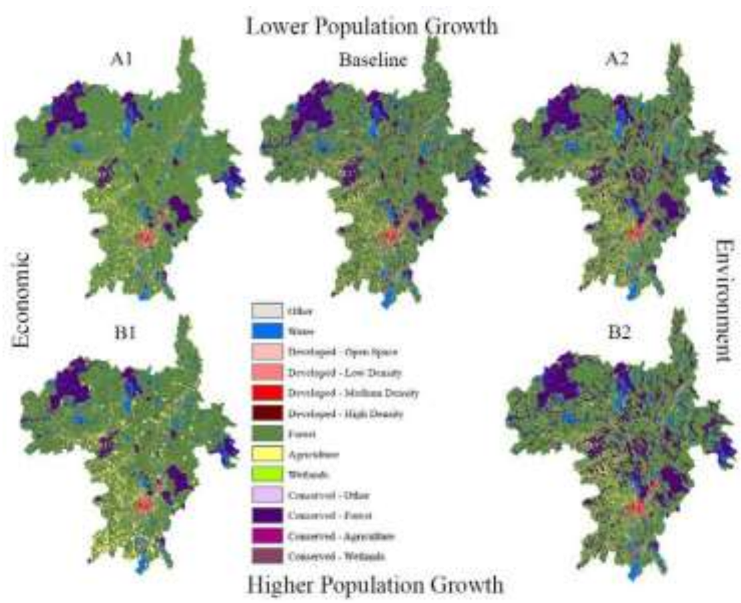


Figure 24 . Scenario results for 2036 showing changes in land use categories.

Assessing the Impact of Development on Forests

We have begun assessing the impact that alternative future development patterns will have on forest cover and wood supply. Figure 25 shows, by town, the areas of greatest increase in land use for each of development, agriculture, and conservation. The next step, which will be conducted in Fall 2014–Spring 2015, is to relate these alternative spatial patterns to the wood supply impacts for each region using FIA data and Maine Forest Service wood supply and silvicultural activities data

.

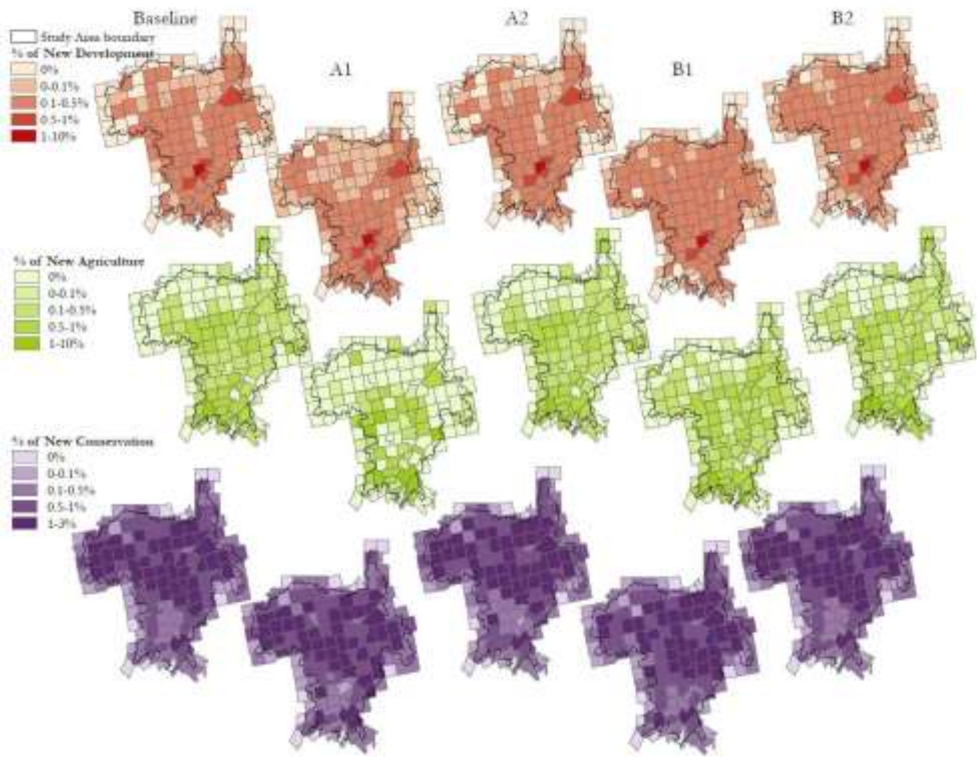


Figure 25 First phase of spatial analysis to determine extent of impact of development and changing land use on forest cover.

The Maine Futures Community Mapper

A related component of this project was to develop a decision support tool to help communities, forest managers, land use planners, conservationists and others identify the areas where conflicts are likely to occur in the future. We developed the Maine Futures Community Mapper (MFCM; www.MaineLandUseFutures.org) to providing the results of our alternative modeling research in an easy-to-use, web-based format for a variety of professionals and volunteers. While this tool will not provide specific wood supply impacts we aim to quantify in this project, it will be a valuable tool for forest managers who wish to work with conservation organizations to ensure lasting access to timber through working forest easements and other conservation tools. Figure 26 shows one tool within the MFCM that allows users to identify areas where forestry and development may be in conflict, as well as areas where there may be opportunities for working forest conservation.

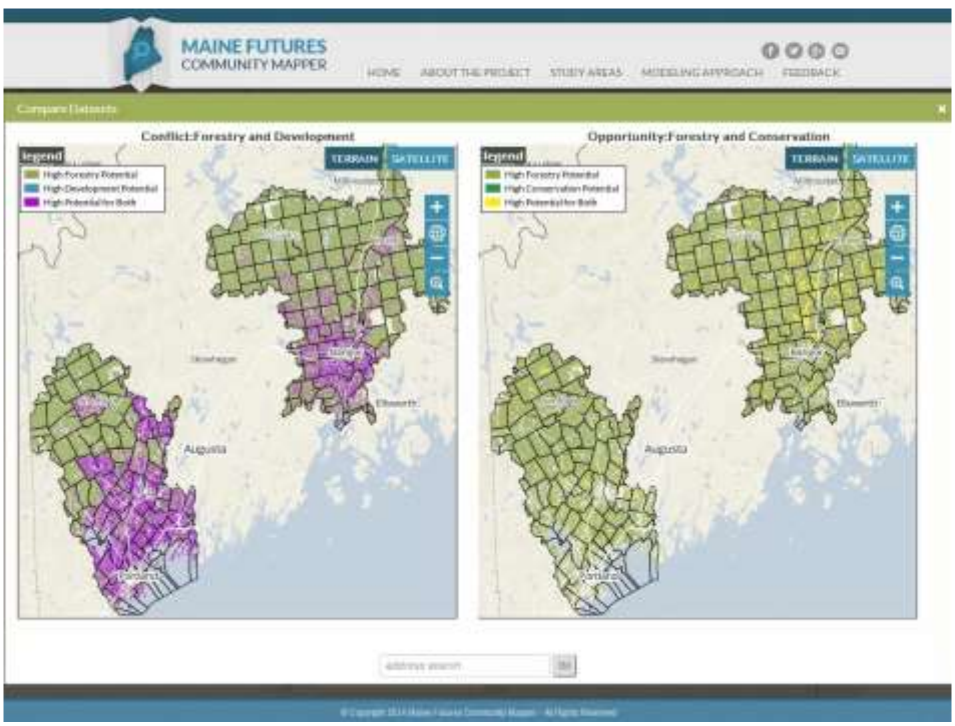


Figure 26 The newly developed Maine Futures Community Mapper (www.MaineLandUseFutures.org) identifies areas of conflict between development and forestry and also opportunities where conservation and forestry are compatible.

Extending the Acadian Variant of the Forest Vegetation Simulator to Intensively Managed Stands

Project Investigators: Aaron Weiskittel*, University of Maine;* John Kershaw*, University of New Brunswick; and* Chris Hennigar*, New Brunswick Department of Natural Resources, Growth and Yield Unit*

Introduction

The Acadian variant of the Forest Vegetation Simulator (FVS) is currently being tested and showing good performance across a range of stand types (Weiskittel et al., 2013). However, the model was mostly developed using data from naturally-regenerated stands and the primary management activities represented are various commercial thinning regimes. Consequently, intensive management activities like vegetation control, pre-commercial thinning (PCT), commercial thinning (CT), and genetics are not well represented. The overall goal of this project was to extend the Acadian variant of FVS to intensively managed stands in the region. The specific objectives were to: (1) compile a regional database of permanent plots in intensively managed stands; (2) test the performance of the current equations across a range of intensive management activities; (3) develop equation modifiers to improve prediction performance; and (4) provide long-term projections of various management regimes.

Summary of Progress: FY 2013-2014

Methods

Initially, existing datasets that included intensive management activities were identified and access to the data was requested. Once the necessary data was obtained, the data were compiled into a standardized database. This included tables for tree, plot, stand, and management treatment information. All tables were standardized to metric, used US Forest Service Forest Inventory and Analysis (FIA) species codes, and removed explicit use of original dataset owner for proprietary reasons. Using plot locational information, climate site index, depth to water table, and other key site attributes were obtained. The tree data was cleaned using custom-built algorithms and plot-level statistics were computed. New datasets continue to be identified and obtained. Once the data is fully compiled, the analysis will proceed in multiple steps. First, the component equations that currently compromise the FVS-AD will be tested using the database. The individual tree equations would include total tree height, height to crown base, diameter increment, height increment, crown recession, and mortality. For each observation, mean bias and absolute bias would be computed and assessed for trends.

Given that equation bias could happen for a variety of reasons above and beyond the true influence of forest management, performance of the equations would be evaluated using an equivalence test. If the prediction error exceeds the specified threshold (e.g. 10-15%) the equation would be considered significantly biased and further refined.

Second, 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. For PCT and CT, the equation would rely on time since treatment, the amount of basal area removed, the type of thinning, and the ratio between mean pre-treatment DBH to post-treatment DBH. For other management activities, the modifier would include covariates relevant to the management activity. The modifier parameter estimates would be estimated using linear and nonlinear mixed effects to better separate between the plot- and management-specific responses.

Finally, the final will 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. Modifiers would be adjustable for local conditions in two main ways: (1) self-calibration (i.e., auto-calibration) of modifiers to reflect tree-level current diameter and height growth rates (if available in tree list), and (2) manual mortality and growth modifier that override commands by species, time period, and tree diameter range. The base FVS-AD and modifiers developed from this study will be 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 will be projected with and without the modifiers and compared to long-term experimental locations like Austin Pond.

Results

A total of 3,065,543 individual tree observations from 20,068 plots were obtained. 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 (Figure 27). 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.

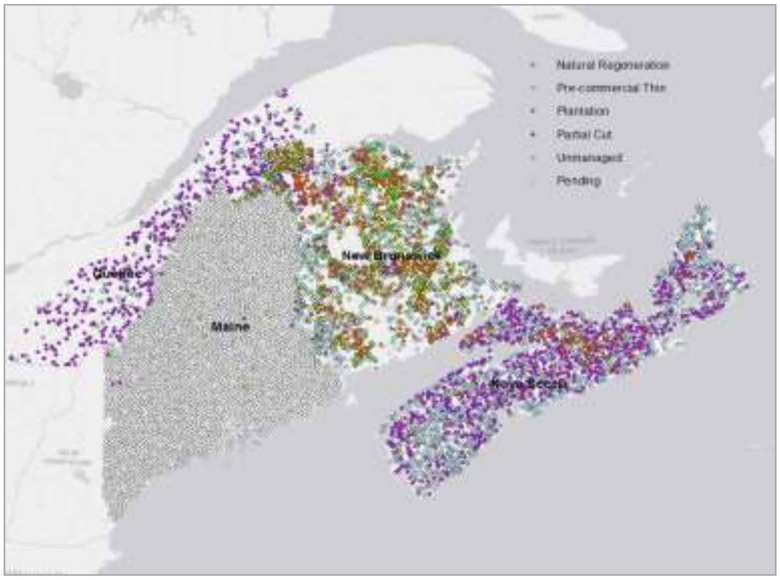


Figure 27 . Location of research plots compiled for analysis by treatment type.

Preliminary analysis using the CFRU Commercial Thinning Research Network Data suggested strong performance of the FVS-ACD total height and height to crown base equations across a range of stand histories and treatment types on average (**Error! Reference source not found.**). However, there was quite a bit of variation in the data, which may be related to site or time since treatment. In general, the total height equation appeared to overpredict red spruce height in the PCT stands, while the no PCT sites showed the highest variation in the ratio between observed to predicted height to crown base.

Discussion

Forest management activities greatly modify residual stand structure and composition, which can make it difficult for regional growth and yield models to accurately predict stand response to treatment. Previous research has clearly shown the Northeastern Variant of FVS (FVS-NE) to be biased in predictions of stand growth response to forest management (Bataineh et al., 2013; Saunders et al., 2008). However, it is difficult to detect whether this bias is due to inherent limitations of FVS-NE or because the model doesn't modify its predictions for certain management activities. This project is attempting to overcome this limitation by ensuring that FVS-ACD accurately reflects both the short- and long-term response to forest management. By compiling an extensive regional database of permanent research plots that have had a range of forest management treatments, this project has a good opportunity to achieve this objective.

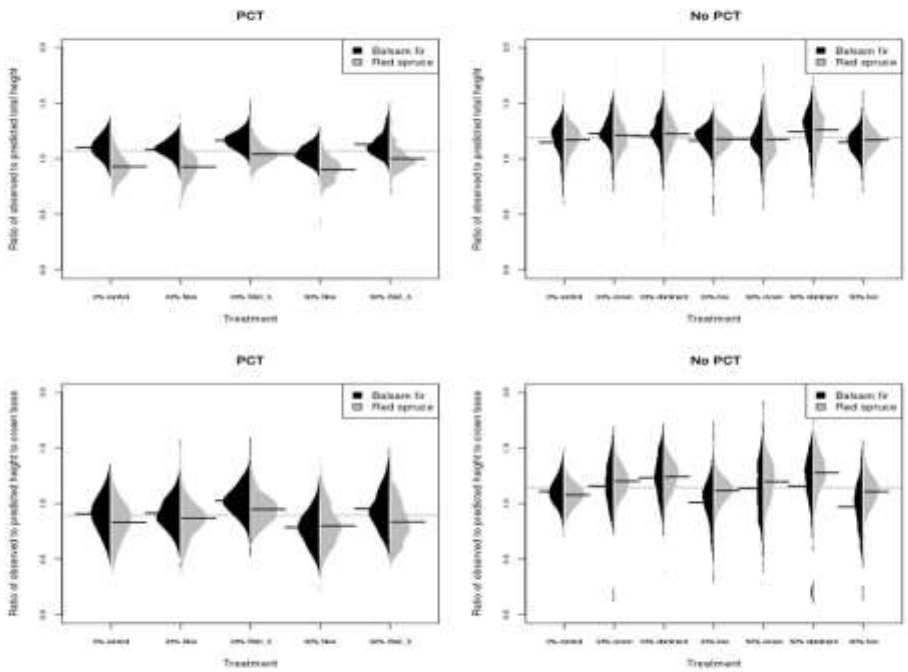


Figure 28 Ratio of observed to predicted height (top) and height to crown base (bottom) by PCT history, treatment type, and species for the CFRU Commercial Thinning Research Network. The predicted values were estimated using the regional equations of FVS- ACD.

It is important that the majority of the managed stand data is coming from Canada and not Maine, which may limit the model's generality. Currently, the only managed stand data is the CFRU CTRN and Austin Pond. These study sites have a wealth of data associated with them, but are not fully representative of the sites where forest management occurs in Maine. Efforts are currently underway to obtain additional managed stand data in Maine. This will be important to ensure that the model is behaving properly across the range of conditions for which it was parameterized for.

Ideally, the regional equations will need limited modification to represent the range of forest management activities. Based on a limited preliminary assessment of the total height and height to crown base equations, they appear to performing quite well for various CT treatments and may not need modification. Diameter and height increment will likely be a different story as growth tends to be more response to management when compared to allometric attributes like total height or height to crown base. Capturing this variation and attributing it to features of the forest management activity like the intensity and type of thinning will be key for success. Another aspect of this project will involve representing and interpreting these forest management activities in a software system. The Open Stand Model (OSM) has been modified to represent a range of management activities. This includes planting and various thinning regimes. In addition to these changes, OSM has been modified in 2 important ways, which should improve its abilities to represent alternative forest projection scenarios. The first is that height and height to crown base predictions can be localized when existing measurements are available. Second, a maximum size-density line that is applicable to mixed-species stands was developed using permanent plots in New Brunswick. This should ensure that stands don't exceed realistic values, even for longer projections (>100 years).

Literature Cited

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. Can. J. For. Res. 43, 385–395.

Saunders, M.R., Wagner, R.G., Seymour, R.S., 2008. Thinning Regimes for Spruce-Fir Stands in the Northeastern United States and Eastern Canada.

Weiskittel, A., Kershaw, J., Hennigar, C., 2013. Refinement of Forest Vegetation Simulator individual- tree growth and yield model for the Acadian Region, in: Roth, B. (Ed.), 2012 Cooperative Forestry Research Unit Annual Report. Orono, ME, pp. 67–77.

Influence of Commercial Thinning on Resistance to and Recovery from Defoliation in Spruce-Fir Forests

Principal Investigator: Michael E. Day, *University of Maine*

Study objectives:

The overarching objective of this study is to establish the physiological basis for greater mortality and loss of productivity associated with balsam fir than red spruce following defoliation by spruce budworm larvae. Specific hypotheses/questions are:

1. Increased carbohydrate reserves (non-structural carbohydrates, NSC) enhance recovery from defoliation in red spruce compared to balsam fir.

2. Post-defoliation foliage in red spruce is more robust due to greater lignin (phenolics) and tannins stimulated by feeding on needles, providing red spruce with enhanced resistance in multiple years of defoliation.

3. The ability to establish NSC reserves for post-defoliation recovery and production of more robust foliage is enhanced by precommercial thinning treatments by increased resource availability.

Summary of Progress: FY 2013-2014

1. Three experimental sites were selected from the University of Maine Cooperative Forest Research Unit Thinning Study sites, each containing unthinned control and thinned stands. Sites represent the diverse spruce-fir forest types in the Northern Forest with one located in the Penobscot Experimental Forest (eastern Maine), one in the central Moosehead Lake region, and the third in north-central Maine, northeast of Baxter Park. At each site, ten trees of each species were selected from both thinned and unthinned stands (40 trees per site). Experimental trees were tagged, mensurational data collected, and GPS coordinates recorded.

2. From all experimental trees, samples for non-structural carbohydrate (starches and sugars) were collected from boles (active xylem through phloem), large roots, large branches and fine branches, and frozen in liquid nitrogen.

3. Two simulated budworm feeding treatments were applied to six branches from each experimental tree. Three branches had all current and year-old needles removed, and three branches had their needles cut at mid-length.4. In the lab, all carbohydrate samples were dried and ground to 40 mesh particle size for carbohydrate analysis.

5. Information on this project has been included in region-wide compendia of research efforts focused on responses to spruce budworm outbreaks.

Projected efforts 2015-2016:

In the next stage of the study, we will continue NSC analysis of ground samples, (2) visit all field sites and collect current year foliage from experimental and control branches and (3) analyze foliar samples for phenolic and tannin content.

A full-time graduate student has joined the program to lead sample and data analysis and will develop a MS thesis based on the results. We anticipate publishing results in peer-reviewed journals and dissemination at regional conferences.

Balsam fir bark - Photo by Pam Wells

Analysis of Wood Resource Availability in the Northeastern United States

Principal Investigator: Jennifer Hushaw, *Innovative Natural Resource Solutions, LLC*
Co-PI: Mark Ducey, *University of New Hampshire*

Summary

This project was undertaken to address the lack of region-wide, consistent datasets that quantify the accessibility of wood supply in terms of the environmental, legal, social, or logistical constraints to harvesting. We are working to fill this data gap by creating a centrally located series of spatial datasets that quantify factors that contribute to the likelihood of harvesting in a given area, such as distance from roads, stream buffers, small parcel size, existing harvest demand, and others.

Methods/Timeline

The first phase of this project, which began in 2014, was a major effort to research and obtain relevant input datasets that would be used for deriving subsequent data layers. In this data acquisition phase, the data sources were downloaded and catalogued to facilitate future documentation requirements.

We are now moving into the second phase of the project, which involves creating the input data layers that spatially represent, or otherwise quantify, the real-world factors that affect the harvesting accessibility of standing timber. Analysis is being carried out using ArcGIS software and documented using the Model Builder feature.

These data layers will be available as stand-alone products for download, but they will also be used as inputs in the creation of the final map product – a map of the relative likelihood of harvesting, showing "hot" and "cold" spots throughout the region, which will provide a more useful baseline for future wood supply estimates. While the input datasets may consist of either continuous or discrete data, they will each go through a reclassification to a relative scale representing harvesting likelihood. When combined, these reclassified spatial datasets will produce a helpful visual representation of the many factors determining the accessibility of local wood supply.

The third phase of the project will involve creation and analysis of the harvest likelihood map, documentation, packaging spatial and tabular datasets for download, and incorporating these data into an existing wood supply modeling tool (Northern Forest Biomass Project Evaluator: www.nefainfo.org/BPE.html)

Summary of Progress: FY 2013-2014

Terrain variables associated with harvesting constraints, including slope steepness and elevation, have been derived for the entire study region. Likewise, a workflow has been developed to generate variable stream/water body buffers based on adjacent slope class and the buffer distances recommended by the Best Management Practices in each state (Figure 29). This workflow generated successful results on a small test area (Figure 30) and will be duplicated for the entire study area.

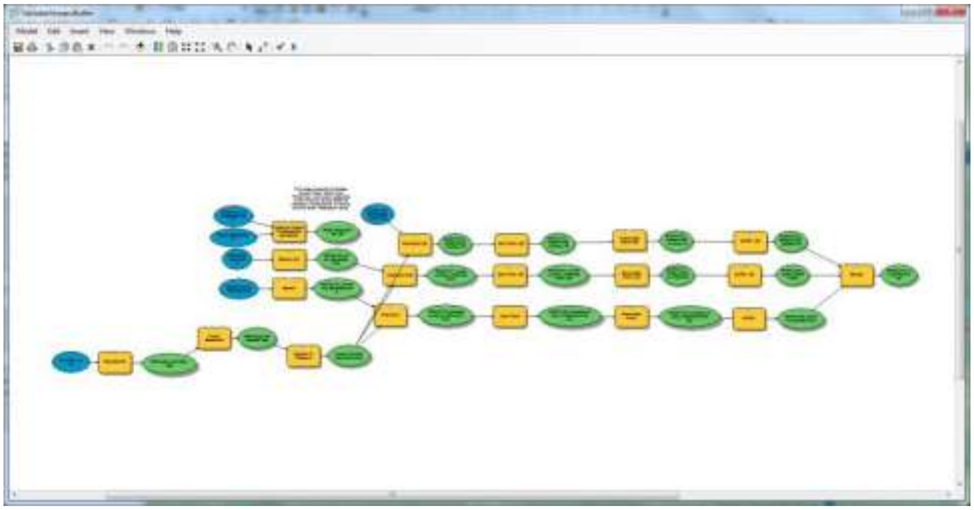


Figure 29 Screenshot of Model Builder workflow for generated variable stream buffers.

Figure 30 Example results from the variable stream buffer analysis – buffers shown in light blue with slope class beneath (from green - relatively flat to red - very steep).

Analysis in Progress

A number of datasets are currently in progress, including a spatial representation of relative market access. Market accessibility is less of an issue for sawtimber, given its relatively high price, which allows these higher-value forest products to remain profitable even when trucked over very large distances. In contrast, pulpwood products are much more dependent on local markets for low-grade wood. The viability of local, low-grade markets can have an important effect on harvesting accessibility in terms of economic feasibility on sites where there is lower quality timber. Consequently, we are working to create a spatial dataset that captures how the location of existing low-grade wood markets (pulp & paper, biomass plants, and pellet mills) affects relative harvesting accessibility in a given area.

Another logistical constraint is the trucking weight limit on local bridges. If harvested material cannot be efficiently moved off-site, the likelihood of harvesting is significantly decreased. We are utilizing data related to existing road networks and the National Bridge Inventory to identify any bottlenecks or pockets of inaccessibility resulting from these conditions.

Social variables also have a strong, although more difficult to measure, influence on the likelihood of harvesting. We are exploring possible methods for linking the results of the National Woodland Owner Survey with data from the US Census to quantify local attitudes toward harvesting that can be incorporated into our final analysis. We are also assembling parcel boundary data for a cross-section of towns in the study area, and overlaying that data on NLCD forest cover and Census data at the town and block level. Our expectation is that we can build regression models to predict the effect of parcelization on operable forest property size using readily available data for the entire study region, including the majority of the region where town-level parcel data are not available.

Outreach

We have submitted an abstract to present this research at the 2014 Eastern CANUSA Forest Science Conference.

Future Distribution and Productivity of Spruce-Fir Forests under Climate Change: A Comparison of the Northeast and the Lake States

Principal Investigator: Erin Simons-Legaard*, University of Maine*
Co-Principal Investigators: Aaron Weiskittel*, University of Maine;* Anthony D'Amato*, University of Minnesota;* Brian Sturtevant*, U.S. Forest Service, Northern Research Station;* Kasey Legaard*, University of Maine*

Project Overview

The vast spruce-fir forests of the Northeast and Great Lakes regions are important economically and ecologically, supporting regional economies and a wide variety of species including many of national (e.g., Canada Lynx, Northern Bog Lemming, Rock Gnome Lichen, Red Crossbill, Spruce Grouse) or global (e.g., Bicknell's Thrush, Red Crossbill, Spruce-fir Moss Spider) conservation concern. Broad-scale climate-envelope models suggest that increasing temperatures and changing patterns of precipitation will reduce the habitat suitability for the primary trees species of the spruce-fir forest type in the U.S. and that remnant trees will experience increased effects of drought and thermal stress. As suitable growing conditions are reduced or eliminated throughout much of the current spruce-fir range, growth and regeneration of hardwood forests or more southerly conifers will be favored. Red Spruce is currently listed as one of the top 10 of species expected to be impacted most by climate change in eastern North American. It is also anticipated that balsam fir will lose a significant portion of its geographic range (~15%) (Potter et al. 2012).

Despite the regional and global importance of spruce-fir forests, projections of future distribution and productivity have to-date been limited to broad scales and coarse climate envelopes. The coarse-scale nature of these models, however, necessarily overlooks the influences of finer-scale variations in environmental and landscape conditions that may allow for local persistence of suitable habitat in a changing climate (Willis and Bhagwat, 2009). Climate refugia have been well-recognized in paleoecological reconstructions of past spruce-fir distribution (e.g., Schauffler and Jacobson 2002). Previous studies have also been limited by data availability and approach. For example, parameterization of climate-envelope models in the U.S. is typically based on U.S. Forest Service Forest Inventory and Analysis (FIA) plot data. Much of the current range, however, is outside the U.S.; thus, the model may underestimate the ability of spruce-fir species to tolerate certain climatic conditions.

Complex interactions between the existing forest, key disturbance agents, and a changing climate have also been ignored in previous projections; thus, they have not addressed the finer scales at which forests are managed. Of particular importance to predicting changes in the distribution of spruce-fir forests are the future spatial and temporal dynamics of spruce budworm outbreaks. Interestingly, outbreak dynamics of spruce budworm populations differ drastically between the Northeast and the Great Lakes, as large, periodic outbreaks are common in the former (Fraver et al. 2007), while small and local infestations are the norm for the latter (Sturtevant et al. 2012). This key distinction between the two regions has important implications for future forest productivity, particularly as climate changes. Understanding the interaction between forest growth and survival under varying pressures from climate change and spruce budworm in the two regions will allow for more effective management and planning of the current resource.

Project Goal and Supporting Objectives

This project will forecast the future productivity and distribution of spruce-fir forest under climate change, taking into account local physiographic features that may provide climate refugia. Using long-term forest-monitoring plots, we will model the historical relationships between site conditions, climate, and tree growth or survival for spruce-fir forest species. Models will be used to predict the presence and growth of this community under competing scenarios of climate change, and relationships between current forest productivity and climate will be explored to identify potential hotspots of productivity. Supporting objectives are to:

1) Produce high-resolution (temporal and spatial) projections of spruce-fir forest type using a meta-modeling framework.

2) Estimate future changes in the distribution and productivity of the spruce-fir forest type due to potential changes in climate.

3) Identify physiographic settings that ameliorate the effects of climate change and provide refugia for spruce-fir tree species.

4) Evaluate the sensitivity of the projected future forest distribution and productivity to disturbance agents like the spruce budworm;

5) Compare the findings for the Northeast to similar work being done in the Great Lake states to understand key differences between regions.

Summary of Progress: FY 2013-2014

An extensive database of growth and yield plot data was compiled in Year 1. The combined dataset includes 9,460,949 unique observations (Figure 31) acquired over 70 years of observation in the Northeast (Maine, Vermont, New Hampshire), the Great Lakes (Michigan, Wisconsin, Minnesota), and Canada (Ontario, Quebec, New Brunswick, Nova Scotia, Newfoundland, Prince Edward Island). Data were collected from multiple private, federal, state, and Canadian provincial agencies in order to ensure models captured the full range of environmental conditions experienced by spruce-fir tree species and to increase model accuracy.

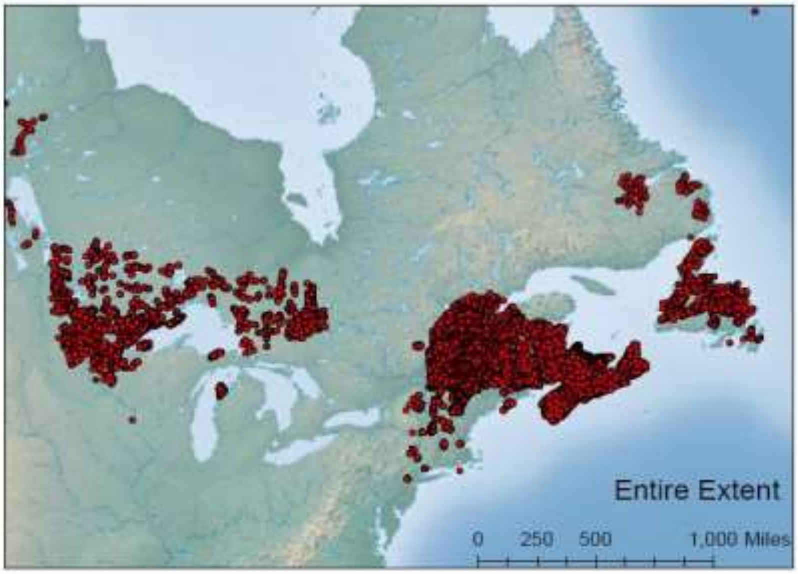


Figure 31 Compiled dataset of growth and yield plots.

Plot data have also been combined with site-specific physiographic information, such as elevation, aspect, parent material, soil water holding capacity, and drainage, to develop bioclimatic profile models for the characteristic species of the spruce-fir habitat (i.e., balsam fir, black spruce, red spruce, and white spruce). Modelling was based on a balanced sampling non-parametric modelling approach, utilizing the 'random forests' package in R (Breiman, 2001), and took place in three phases. First, the Acadian and Great Lakes spruce-fir forests were each modelled separately, and then the entire dataset was modelled as a whole. This approach ensured accurate representation of regional differences in forest composition (i.e., *Picea rubens'* range does not extend out of the Acadian forest) as well as topography (e.g. the Northeast is more topographically diverse than the Midwest). The size of the plot dataset led to an increase in computational time, as well as the development of techniques to check accuracy of a dataset that is not readily visualized. Preliminary results indicate high measures of accuracy in model fits. Models of presence and absence were predicted on the current landscape and compared to actual known presence and absence to assess accuracy based on the area under receiver operating curve (AUC) (Fielding and Bell 1997). The average AUC value across models was 0.91.

Preliminary analyses using models to forecast spruce-fir habitat under different climate change scenarios has also been completed. Projections of suitable habitat for red spruce in Maine, for example, suggest a substantial decline by the year 2090, with habitat refuges maintained in high elevation zones and along shorelines (Figure 32).

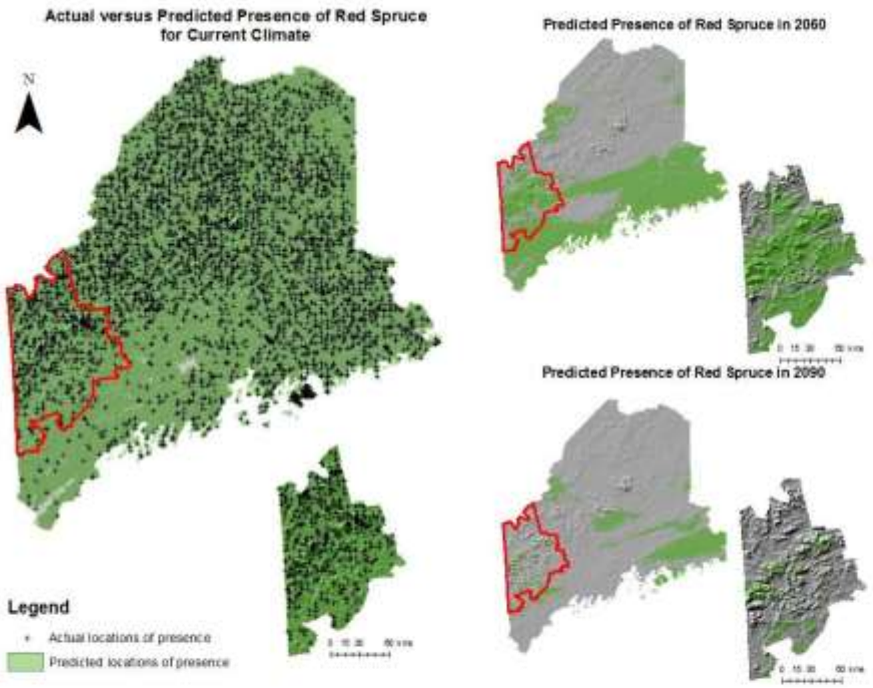


Figure 32 Predicted red spruce presence in present time, 2060, and 2090, at multiple scales. AUC for this model is .96. The Hadley Centre for Climate Prediction and Research B2 scenario was used for future predictions

Literature Cited

Breiman, L.E.O., 2001. Random Forests. Machine Learning 45: 5–32.

Fielding, A.H., J.F. Bell. 1997. A review of methods for the assessment of prediction errors in conservation presence-absence models. Environmental Conservation 24: 38-49.

Fraver, S., R.S. Seymour, J. H. Speer, and A.S. White. 2007. Dendrochronological reconstruction of spruce budworm outbreaks in northern Maine. Canadian Journal of Forest Research 37: 523-529.

Potter, K.M., Crane, B.S., Hargrove, W.W., 2012. Adapt, move, or die: FIA data in assessments of forest tree genetic degradation risk from climate change and other threats. Morin, R.S., Liknes, G.C. (Eds.), General Technical Report NRS-P-105. US Forest Service, Northern Research Station, p. 104.

Schauffler, M., Jacobson Jr., G.L., 2002. Persistence of coastal spruce refugia during the Holocene in northern New England, USA, detected by stand-scale pollen stratigraphies. Journal of Ecology 90: 235-250.

Sturtevant, B., B. Miranda, D. Shinneman, E. Gustafson, and P. Wolter. 2012.Comparing modern and presettlement forest dynamics of a sub boreal wilderness: Does spruce budworm enhance fire risk? Ecological Applications 22: 1278-1296.

Willis, K.J., Bhagwat, S.A., 2009. Biodiversity and climate change. Science 326: 806.

Quantifying the Influence of Stand Spatial Structure and Species Composition on Forest Growth and Regeneration Patterns: Evaluating the Role of Distance-dependent Competition Indices within the Acadian Variant of the Forest Vegetation Simulator

Principal Investigators: Aaron Weiskittel, Shawn Fraver, and Christian Kuehne, *University of Maine*

Summary of Progress: FY 2013-2014

This NSRC project started July 2013 and has made good progress since then. In November, Dr. Christian Kuehne was hired as post-doctorate researcher and is primarily funded from this NSRC project. Since November, Dr. Kuehne has been working to compile the regional

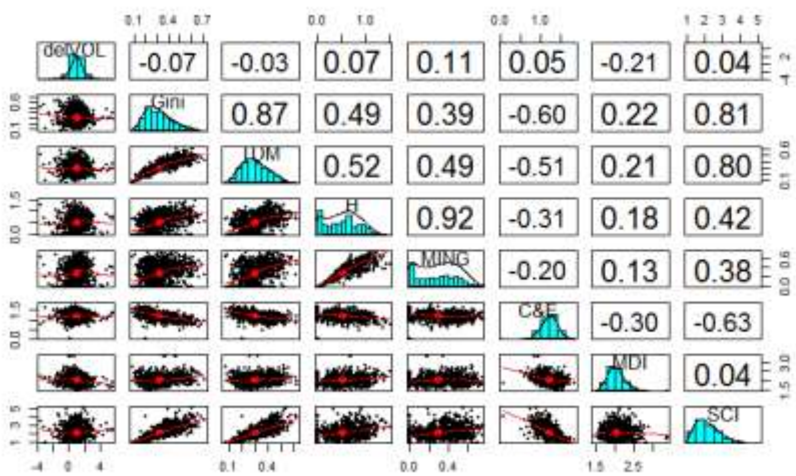


Figure 33 . Pearson correlation coefficients between annualized stand volume growth (m3 ha-1 yr-1) and various structural indices including the Gini coefficient for DBH, tree differentiation metric (TDM), Shannon-Weaver index on height (H), Ming species different

permanent sampling plots with tree spatial information, refining the computer code developed by Dr. Justin Waskiewicz, and applying the code to some data for preliminary analysis. Issues with the data are currently being resolved such as inaccurate tree locations, measurement inconsistencies, and incompatible formats. The computer code has been completed and is currently being documented and tested. Preliminary results suggest that tree spatial information are more related to stand-level mortality patterns than growth, but the promising indices are the mean size differential index and a species differential index (Figure 33). In the coming year, this analysis will be extended to more sites, focus on individual trees rather than stands, and work on developing the modifiers needed for the Acadian Variant of the Forest Vegetation Simulator.

Mixed stand after pre-commercial thinning - photo by Pam Wells

Center for Advanced Forestry Systems

This past year represented the fifth and final year of Phase I participation in CAFS, which is a multi-university center that works to solve forestry problems using multifaceted 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, Auburn University, Oregon State University, Purdue University, Virginia Tech, University of Georgia, University of Washington, University of Idaho, and University of Florida.

A proposal to the National Science Foundation for CFRU to participate in a second five-year phase of CAFS was successful this year. CAFS Phase II provides $60,000 per year to the University of Maine and CFRU members to advance growth and yield models for natural forest stands in the Northeast. This year CAFS provided funding for two research projects: (1) Extension of the Acadian Variant of the Forest Vegetation Simulator (FVS) to Intensively Managed Stands and (2) Individual-Tree Response to Commercial Thinning in Northern Maine. 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 pre-commercial and commercial thinning. This information is critical for harvesting scheduling, financial assessment, and efficient silvicultural decisions. CAFS funding supported graduate student Cen Chen, PhD, and two post-doctorate researchers (Mohammad Bataineh and Christian Kuehne).

Continued participation in Phase II of CAFS was pursued with a formal proposal to NSF. The proposal was officially accepted, which means that the University of Maine will remain part of CAFS for another 5 years.

Howland Research Forest

Howland Forest is a continuously operating forest ecosystem research site established in 1986 by University of Maine researchers with the cooperation of International Paper. It is located approximately 30 miles north of Orono, Maine, and situated within an expansive low elevation conifer/northern hardwood transitional forest. The forest is dominated by spruce and hemlock with an average stand age of 140 years. Initially funded to conduct biogeochemical cycling and acid rain research, Howland Forest has since been host to various model and sensor development efforts as well as numerous studies focusing on nutrient cycling, forest ecology, ecosystem modeling, acid deposition, remote sensing, climate change, and carbon sequestration. Already a member of several research networks, Howland Forest became the first base site for the Ameriflux network in 1996. The current research focus is based around our ability to measure the flux of carbon dioxide (i.e., the forest-atmosphere exchange). This, along with the many ancillary ecological and atmospheric data measurement systems, provides valuable information about how the landscape breathes and grows, and is the foundation for related research to further our understanding of how the environment works.

View from Howland monitoring tower - photo by Spencer Meyer

Sustainability Solutions Initiative

Connecting knowledge with action in ways that promote strong economies, vibrant communities, and healthy ecosystems in and beyond Maine.

Through its *Conservation Lands Program*, CRSF maintains an active partnership with and benefits from ongoing support by 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 2014, several projects in the Conservation Lands Program benefitted from ongoing financial support.

ssi maine's sustainability solutions initiative

Red pine stand - photo by Pam Wells

Forests for Maine’s Future

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 value that Maine’s forests have to the public. More than 4,500 readers subscribe to FMF articles and newsletters.

With support from the Maine Outdoor Heritage Fund last year, FMF has been able to develop a social media presence through Facebook, Twitter, and a new FMF blog. This expanded social media presence has allowed FMF to spread the word about Maine’s forests more effectively and to a broader audience. Details about FMF’s new communication efforts can be seen at: http://www.forestsformainesfuture.org

Appendices

Publications and Presentations

CRSF scientists disseminated results from their research in a wide variety of ways this year. They delivered 28 journal publications, 3 book chapters, 11 research reports and working papers, 3 conference proceedings, 4 theses, 4 policy briefs, and 43 presentations (including posters, filed tours, media presentations, and workshops).

Journal Publications

Bataineh, M. M., Kenefic, L., Weiskittel, A. R., Wagner, R. G., & Brissette, J. 2013. Influence of partial harvesting and site factors on the abundance and composition of natural regeneration in the Acadian Forest of Maine, USA. *Forest Ecology and Management, 306*:96–106.

Bataineh, M. M., Wagner, R. G., Olson, M. G., & Olson, E. K. 2013. Midrotation response of ground vegetation to herbicide and precommercial thinning in the Acadian Forest of Maine, USA. *Forest Ecology and Management, 313*: 132–143.

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*: 385–395.

Bell, K., Lindenfeld, L., Speers, A., Teisl, M., & Leahy, J. 2013. Creating Opportunities for Improving Lake-focused Stakeholder Engagement: Knowledge-action Systems, Pro-environment Behaviour and Sustainable Lake Management. *Lakes & Reservoirs: Research & Management*, *18*: 5–14.

Benjamin, J. G. 2013. No free lunch in the woods: An economic reality check for proponents of biomass harvesting. *Atlantic Forestry Review, 20*: 20–21.

Day, M.E., S. Zazzaro and L.B. Perkins. 2014. Seedling ontogeny and environmental plasticity in two co-occurring shade-tolerant conifers and implications for environment-population interactions. *American Journal of Botany, 101*: 45–55.

Hiesl, P., & Benjamin, J. G. 2013. A multi-stem feller-buncher cycle time model for partial harvest of small diameter wood stands. *International Journal of Forest Engineering, 24*:101–108.

Hutchins, K., Lindenfeld, L., Bell, K., Leahy, J., & Silka, L. 2013. Strengthening Knowledge Co-Production Capacity: Examining Interest in Community-University Partnerships. *Sustainability*, *5*: 3744–3770.

Jansujwicz, J., A.J.K. Calhoun, J. E. Leahy, and R. J. Lilieholm. 2013. Using Mixed Methods to Develop a Frame-based Private Landowner Typology. *Society and Natural Resources, 26*:945–961.

Leahy, J., & Gorczyca, E. 2013. Agent-based Modeling of Harvest Decisions by Small Scale Forest Landowners in Maine, USA. *International Journal of Forest Research*, 2: 1–13.

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, 55*(4):3–14.

Lyons, P., Leahy, Jessica E., Lindenfeld, L., & Silka, L. 2014. Knowledge to Action: Implicit Knowledge Production Models Held Among Forest Science Researchers. *Society & Natural Resources*. DOI: 10.1080/08941920.2013.861552

Manik, Y., Leahy, J., & Halog, A. 2013. Social Life Cycle Assessment of Palm Oil Biodiesel: A Case Study in Jambi Province of Indonesia. *International Journal of Life Cycle Assessment*, *18*: 1386–1392.

Meyer, S. R., Cronan, C. S., Lilieholm, R. J., Johnson, M. L., & Foster, D.R. in press. Using the Historical Roots of Land Conservation in Northern New England to Derive Alternative Future Scenarios of Landscape Conservation. *Conservation Biology*.

Meyer, S. R., Johnson, M.L., Lilieholm, R. J., & Cronan, C. S. in press. Development of a Stakeholder-driven Spatial Modeling Framework for Strategic Landscape Planning using Bayesian Networks across two Urban-Rural Gradients in Maine. *Ecological Modeling*.

Nelson, A. S., Wagner, R. G., Saunders,M. R., & Weiskittel, A. R. 2013. Influence of management intensity on the productivity of young early successional Acadian stands in eastern Maine. *Forestry, 86*: 79–89.

Nelson, A. S., Weiskittel, A.R., Wagner, R.G., & Saunders, M.R. In press. Development and evaluation of aboveground small tree biomass models for naturally regenerated and planted tree species in eastern Maine, U.S.A. *Biomass and Bioenergy*.

Nelson, A. S., Weiskittel, A. R., & Wagner, R.G. 2014. Development of branch, crown, and vertical distribution leaf area models for contrasting hardwood species in Maine, U.S.A. *Trees - Structure and Function, 28*: 17–30.

Olson, M. G., Meyer, S. R., Wagner, R. G., & Seymour, R. S. 2014. Commercial thinning stimulates natural regeneration in spruce–fir stands. *Canadian Journal of Forest Research. 44*(3): 173–181.

Rice, B., Weiskittel, A.R., & Wagner, R.G. 2014. Efficiency of alternative forest inventory techniques in partially harvested stands of Maine. *European Journal of Forest Research 133*: 261–272.

Roxby, G., & 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.

Russell, M. B., Weiskittel, A. R., & Kershaw, J. A. 2013. Benchmarking and calibration of Forest Vegetation Simulator individual tree attribute predictions across the northeastern US. *Northern Journal of Applied Forest Research, 30*: 75–84.

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

Smith, J., Anderson, D., Davenport, M. & Leahy, J. 2013. Community Benefits from Managed Resource Areas. *Journal of Leisure Research*, *45*: 192–213.

Smith, J., Leahy, J., Anderson, D., Davenport, M. 2013. Community/Agency Trust and Public Involvement in Resource Planning. *Society & Natural Resources*, *26*: 452–471.

Smith, J., Leahy, J., Anderson, D., & Davenport, M. 2013. Community/Agency Trust: A Measurement Instrument. *Society & Natural Resources*, *26*: 472–477.

Snell, M., Bell, K., & Leahy, J. 2013. Local Institutions and Lake Management. *Lakes & Reservoirs: Research & Management*, *18*: 35–44.

Wang, Z., Schaaf, C. B., Strahler, A. H., Chopping, M.J., Román, M. O., Shuai, Y., Woodcock, C. E., Hollinger, D.Y., & Fitzjarrald, D. R. 2014. Evaluation of MODIS albedo product (MCD43A) over grassland, agriculture and forest surface types during dormant and snow- covered periods. *Remote Sensing of Environment, 140*: 60–77.

Books, Book Chapters, & Editorships

Leahy, J., & Lindenfeld, L. 2013. Linking Knowledge with Action: Applied Social Science Considerations to Improve Woody Bioenergy Research and Development Effectiveness. In M. Jacobson & D. Ciolkosz (Eds.), *Wood-Based Energy in the Northern Forests* (p. 209–217). New York: Springer.

Lilieholm, R. J., Cronan, C. S., Johnson, M., Meyer, S., & Owen, D. 2014. Alternative Futures Modeling in Maine's Penobscot River Watershed: Forging a Regional Identity for River

Restoration. In J. Levitt (Ed.), *Academic Institutions as Conservation Catalysts*. Washington, DC: Island Press.

Lilieholm, R. J., & Eaton, M.. 2013. Land as Sustenance and Sanctuary: Settlement History and Resource Use in and around Utah's Grand Staircase-Escalante National Monument. In J. B. Smith (Ed.), *National Parks: Sustainable Development, Conservation Strategies, and Environmental Effects* (Ch. 6, pp. 179–200). New York: Nova Science Publishers.

Research Reports and Working Papers

Harrison, D., Simons-Legaard, E., Legaard, K., & Sader, S. 2013. *Effectiveness of Zoning to Protect Deer Wintering Habitats in Maine: Did the Designation of LURC-zoned Deeryards Achieve Desired Objectives during the Period 1975–2007?* Final report to the Northeastern States Research Cooperative and USDA Forest Service.

Lilieholm, R. J., Cronan, C. S., Johnson, M., Meyer, S., & Owen, D. 2013. *Alternative Futures Modeling in Maine's Penobscot River Watershed: Forging a Regional Identity for River Restoration*. Lincoln Institute of Land Policy, Cambridge, MA, Working Paper WP12RL1.

Nelson, A. S., Wagner, R. G., & Saunders, M. R. 2014. Silvicultural Options for Early-Successional Stands in Maine: Six-Year Results of the Silvicultural Intensity and Species Composition Experiment. In L. S. Kenefic & J. C. Brissette (Comp.), *Penobscot Experimental Forest: 60 Years of Research and Demonstration in Maine, 1950–2010*. U.S. Department of Agriculture, Forest Service, Northern Research Station, Gen. Tech. Rep. NRS-P-123.

Nelson, A., Wagner, E., & Weiskittel, A. 2013. Verification of Regional and National Aboveground Sapling Biomass Equations in Maine. In B. Roth (Ed.), *Cooperative Forestry Research Unit: 2012 Annual Report.* University of Maine, Orono, ME.

Olson, M., Meyer, S., Wagner, R., & Seymour, R. 2013. Response of Tree Regeneration to Commercial Thinning in Spruce-Fir Stands of Maine: First Decade Results from the Commercial Thinning Research Network. In B. Roth (Ed.), *Cooperative Forestry Research Unit: 2012 Annual Report.* University of Maine, Orono, ME.

Rice, B., Wagner, R., & Weiskittel, A. 2013. Residual Conditions of 50 Partially Harvested Stands in Northern Maine. In B. Roth (Ed.), *Cooperative Forestry Research Unit: 2012 Annual Report.* University of Maine, Orono, ME.

Roth, B., Wagner, R., Seymour, R, Weiskittel, A.,Brockmann, D., & and Benjamin, J. 2013. Austin Pond Study: Third wave update. In B. Roth (Ed.), *Cooperative Forestry Research Unit: 2012 Annual Report.* University of Maine, Orono, ME.

Roth, B., Wagner, R., Seymour, R., Weiskittel, A., & Meyer, S. 2013. Commercial Thinning Research Network: 2012 Update. In B. Roth (Ed.), *Cooperative Forestry Research Unit: 2012 Annual Report.* University of Maine, Orono, ME.

Saunders, M. R., Seymour, R. S., & Wagner, R. G. 2014. The Acadian Forest Ecosystem Research Program: An Example of Natural Disturbance-based Silviculture in the Northeast. In L. S. Kenefic & J. C. Brissette (Comp.), *Penobscot Experimental Forest: 60 Years of Research and Demonstration in Maine, 1950–2010*. U.S. Department of Agriculture, Forest Service, Northern Research Station, Gen. Tech. Rep. NRS-P-123.

Seymour, R. S., Meyer, R. S., & Wagner, R. G. 2014. The Cooperative Forestry Research Unit Commercial Thinning Research Network: 9-Year Results. In L. S. Kenefic & J. C. Brissette (Comp.), *Penobscot Experimental Forest: 60 Years of Research and Demonstration in Maine, 1950–2010*. U.S. Department of Agriculture, Forest Service, Northern Research Station, Gen. Tech. Rep. NRS-P-123.

Wagner, R. G., & A. Weiskittel. 2013. Center for Advanced Forestry Systems (CAFS). In B. Roth (Ed.), *Cooperative Forestry Research Unit: 2012 Annual Report.* University of Maine, Orono, ME.

<u>Conference Proceedings</u>

Hiesl, P., & Benjamin, J. G. June 2014. "Harvester and Feller-Buncher Productivity and Cost in Small Diameter Timber Stands in Central Maine, USA." In *Proceedings of the 37th Council on Forest Engineering: Global Harvesting Technology*, Moline, IL.

Hiesl, P., & Benjamin, J. G. July 2013. "Assessment of Feller-Buncher and Harvester Caused Stand Damage in Partial Harvests in Maine." In *Proceedings of the 36th Council on Forest Engineering: Forest Operations for a Changing Landscape*, Missoula, MT.

Nelson, A. S., Weiskittel, A. R., Wagner, R. G., & Saunders, M. R. 2012. Verification of the Jenkins and FIA Sapling Biomass Equations for Hardwood Species in Maine. In R. S. Morin & G. C. Liknes (Ed.), *Moving from Status to Trends: Forest Inventory and Analysis (FIA) Symposium*, Baltimore, MD. USDA Northern Research Station, Gen. Tech. Rep. NRS-P-105

<u>Theses</u>

Clune, P. M. 2013. Growth and development of Maine spruce-fir forests following commercial thinning. M.S. thesis, University of Maine, Orono.

Hiesl, P. A. 2013. Productivity standards for whole-tree and cut-to-length harvesting systems in Maine. M.S. thesis, University of Maine, Orono.

Nelson, A. S. 2013. Production ecology and stand dynamics of young Acadian forest stands in response to silvicultural intensity and compositional objectives. Ph.D. dissertation. University of Maine, Orono.

Schmidt, D. 2014. Modeling Growth and Mortality of Northern Hardwoods in Even-Aged Stands in the Adirondacks. M.Sc. thesis. SUNY College of Environmental Science and Forestry, Syracuse, NY.

Policy Briefs

Lilieholm, R. J. Apr 2014. Projected Future Fencing South of Nairobi National Park. *Gnu Landscapes Policy Brief No. 2*. http://www.nrel.colostate.edu/projects/gnu/

Lilieholm, R. J. Apr 2014. Effects of Unplanned Development in the Region South of Nairobi National Park*. Gnu Landscapes Policy Brief No. 3*. http://www.nrel.colostate.edu/projects/gnu/

Lilieholm R. J. Apr 2014. Projected 2035 Development and Fencing for the Region South of Nairobi National Park. *Gnu Landscapes Policy Brief No.4.* http://www.nrel.colostate.edu/projects/gnu/

Lilieholm R. J. Apr 2014. Planning Tools for Managing Growth in the Region South of Nairobi National Park. *Gnu Landscapes Policy Brief No. 5*. http://www.nrel.colostate.edu/projects/gnu/

Presentations, Posters, Field Tours, Media, and Workshops

Bataineh, M., Kenefic, L., Weiskittel, A., Wagner, R., & Brissette, J. Oct 2013. Influence of partial harvesting and site factors on the abundance and composition of natural regeneration in the Acadian Forest of Maine, USA. Silviculture Matters, Society of American Foresters National Convention, North Charleston, South Carolina, Poster Presentation.

Bataineh, M., Nelson, A., Wagner, R., Roth, B., & Weiskittel, A. May 2014. Individual-tree response to commercial thinning in northern Maine: influence of including competition, site, and treatment regime in growth and yield models. National Science Foundation, Center for Advanced Forestry Systems (CAFS) 2014 Annual Meeting, Coeur d´ Alene, ID.

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

Leahy, J. May 2014. May 2014. 1st Annual New England Wood Bank Summit, workshop, Norwich, VT.

Leahy, J., Straub, C., & Snell, M. May 2014. "Understanding Landowner Risk Perceptions and Social Acceptability toward Invasive Forest Pests." IUFRO Small Scale Forestry Conference, Sopron, Hungary.

Leahy, J., Straub, C., & Snell, M. Mar 2014. "Forest Pest Knowledge, Attitudes & Behaviors among Family Forest Landowners: Regional Survey Results." Northeast Forest Pest Council Meeting, Quebec City, Canada.

Lilieholm, R. J. June 2014. “Future Forest Scenarios.” Pacific Northwest College of the Arts, Portland, OR.

Lilieholm, R. J. June 2014. Training workshop for the Maine Futures Community Mapper, Eastern Maine Development Corp and the University of Maine, Nutting Hall, Orono.

Lilieholm, R. J. May 2014. “Alternative Futures Modeling: Understanding the Past, Envisioning the Future.” College of the Atlantic, Bar Harbor, Maine; Institute of Forestry, Pokhara, Nepal; and Kathmandu Forestry College, Nepal.

Lilieholm, R. J. Apr 2014. “Alternative Future Land-use Scenarios for Kenya’s National Parks and Protected Areas.” UMaine School of Biology and Ecology, Orono.

Lilieholm, R. J. Mar 2014. “Alternative Futures Modeling: Understanding the Past, Envisioning the Future.” Kenya Wildlife Service, Nairobi National Park, and University of Nairobi, Kenya.

Lilieholm, R. J. Feb. 2014. “Landowners Cash In on Timber They Don’t Cut.” *Portland Press Herald* and the *Maine Sunday Telegram*, February 16, 2014. http://www.pressherald.com/news/Landowners_cash_in_on_timber_they_don_t_cut_.html?pagenum=full).

Lilieholm, R. J. Jan. 2014. “Maine’s Bay-to-Baxter Initiative: Promoting Economic Development and Quality-of-Place in the Penobscot River Watershed.” ALPINE - Academics for Land Protection in New England. Harvard Forest, Petersham, MA. January 10, 2014. (Lilieholm presenting, with Meyer, Johnson, Cronan, and Owen).

Lilieholm, R. J. Nov. 2013. Conservation Management “Best Practices” Workshop, University of New Brunswick, Fredericton, New Brunswick.

Lilieholm, R. J. Nov. 2013. “New England Cranks up its Wood-burning Stoves.” *NPR’s Marketplace*, produced by Jack Rodolico.

http://www.marketplace.org/shows/marketplace/marketplace-friday-november-1-2013).

Lilieholm, R. J. Oct. 2013. “Sustainable Maine: Preserving Paradise – Mapping Maine’s Future.” 30-minute *MPBN television special* on the SSI Alternative Futures Project. http://www.mpbn.net/Television/LocalTelevisionPrograms/SustainableMaine/PreservingParadise.aspx)

Lilieholm, R. J. July 2013. “Alternative Futures Modeling in Maine: Understanding the Past ... Envisioning the Future.” Acadian Internship Program, Acadia National Park. (Lilieholm and Meyer presenting, with Cronan and Johnson).

Lilieholm, R. J. 2013. Conservation Catalysts Network, Lincoln Institute of Land Policy, Cambridge, MA.

Meyer, S. May 2014. Maine Land Trust Alliance Annual Meeting, Topsham, Maine. (Meyer presenting, with Lilieholm).

Nyland, R. D. June 2014. “Rehabilitating Disturbed Forests: Where We Stand and What We Need.” A presentation at the Forest Stand Rehabilitation Workshop Empire State Forest Products Association, Timber Harvesters Training Program, Tully, NY.

Nyland, R. D. June 2014. “Rehabilitating Northern Hardwoods in the Aftermath Forest.” Field tour for staff of Menomonee Enterprises at Huntington Wildlife Forest, Newcomb, NY.

Nyland, R. D. Sep 2013. “Rehabilitating Disturbed Forests.” A nation-wide webinar for East Technology Support Center, Natural Resources Conservation Service.

Nyland, R. D. July 2013. “Rehabilitating Northern Hardwoods in the Aftermath Forest.” Field tour for staff of Fountain Forestry, Inc., at Huntington Wildlife Forest, Newcomb, NY.

Silver, E. J., Leahy, J. E., Noblet, C., Kittredge, D. B., & Weiskittel, A. W. June 2014. “Risk Perception and Relevance of Timber Harvesting for Bioenergy Production: A Qualitative Examination of Private Woodland Owners.” International Symposium for Society and Resource Managers, Hannover, Germany

Silver, E. J., Leahy, J. E., Noblet, C., Kittredge, D. B., & Weiskittel, A. W. Mar 2014. “Risk Perception and Relevance of Timber Harvesting for Bioenergy Production: A Qualitative Examination of Private Woodland Owners.” *New England Society of American Foresters Annual Meeting,* Nashua, NH.

Silver, E. J., Leahy, J. E., Noblet, C., Kittredge, D. B., & Weiskittel, A. W. Apr 2014. “Risk Perception and Relevance of Timber Harvesting for Bioenergy Production: A Qualitative

Examination of Private Woodland Owners." Maine Water and Sustainability Conference, Augusta, ME.

Silver, E. J., Leahy, J. E., Kittredge, D. B., Noblet, C., & Weiskittel, A. W. Oct 2013. "Private Woodland Owner Timber Harvesting Behavior: The Difference between Attitudes, Intentions, and Behavior." Society of American Foresters National Convention, Charleston, SC.

Wagner, R. G. May 2014. "Results from CFRU Thinning Research." 7-Islands Land Company Annual Forestry Meeting, Penobscot Experimental Forest, Bradley, ME.

Wagner, R. G. May 2014. "Overview of CFRU Research." Wagner Forest Management Annual Forestry Staff Meeting, Comstock, ME.

Wagner, R. G. Apr 2014. "The Spruce Budworm is Knocking at Our Door Once Again: How Is Maine Planning to Answer?" Maine Pesticide Recertification Meetings, Spectacular Event Center, Bangor, and Ramada Inn, Lewiston, ME.

Wagner, R. G. Mar 2014. "Spruce Budworm – Human Response Cycle: How It Shaped Everything in Maine Forestry for the Past 40 Years." NERCOFE Workshop, University of Maine, Orono.

Wagner, R. G. Mar 2014. "Maine SBW Outbreak Assessment, Preparation & Response Strategy: Wood Supply Impacts." NERCOFE Workshop, University of Maine, Orono.

Wagner, R. G. Dec 2013. "Overview of Center for Sustainable Forests Research." University of Maine Research Center Director's Meeting, University of Maine, Orono.

Wagner, R. G. Oct 2013. "Spruce Budworm – Human Response Life Cycle: How It Shaped Everything in Maine Forestry for the Past 40 Years." Forestry Noontime Seminar, School of Forest Resources, University of Maine, Orono.

Wagner, R. G. Oct 2013. "Influence of Partial Harvesting on Hardwood Regeneration. Financially Feasible Hardwood Silviculture: Sustaining a Competitive Hardwood Value Chain." Edmundston, NB.

Wagner, R. G. Sept 2013. "Maine Spruce Budworm Strategy Plan." Maine Forest Products Council 53rd Annual Meeting, Sugarloaf, ME.

Wagner, R. G. Sept 2013. "Spruce Budworm – Human Response Life Cycle: How It Shaped Everything in Maine Forestry for the Past 40 Years." Maine Forest Products Council, 53rd Annual Meeting, Sugarloaf, ME.

Wagner, R. G. Sept 2013. “Importance of Wood & Future Long-term Drivers for Forest Industry.” Maine Forest Products Council, 53rd Annual Meeting, Sugarloaf, ME.

Wagner, R.G., Bataineh, M., Olson, M.G., Nelson, A.S., Rice, B. 2013. “Influence of Partial Harvesting on Hardwood Regeneration.” Presented at: Northern Hardwood Research Institute Fall Meeting. Edmundston, New Brunswick, Canada.

Weiskittel, A. May 2014. Forest modeling research in Maine. Invited seminar. Northern Hardwoods Research Institute. University of Moncton, Edmundston, New Brunswick.

Weiskittel, A. R. Mar 2014. Climate change and forest growth modeling: The uncertainty of predicting the unknown. Invited seminar. Michigan State University Hanover Seminar Series. East Lansing, MI.

Weiskittel, A. R. Oct 2013. Development of a regional growth and yield model for complex, managed stands of the Acadian Forest. IUFRO Meeting on Complex Forest Ecososytems. New Orleans, LA.

Weiskittel, A.R. Oct 2013. Linking growth and wood quality models: Past, present, and future. MeMoWood Conference. Invited keynote. Nancy, France.