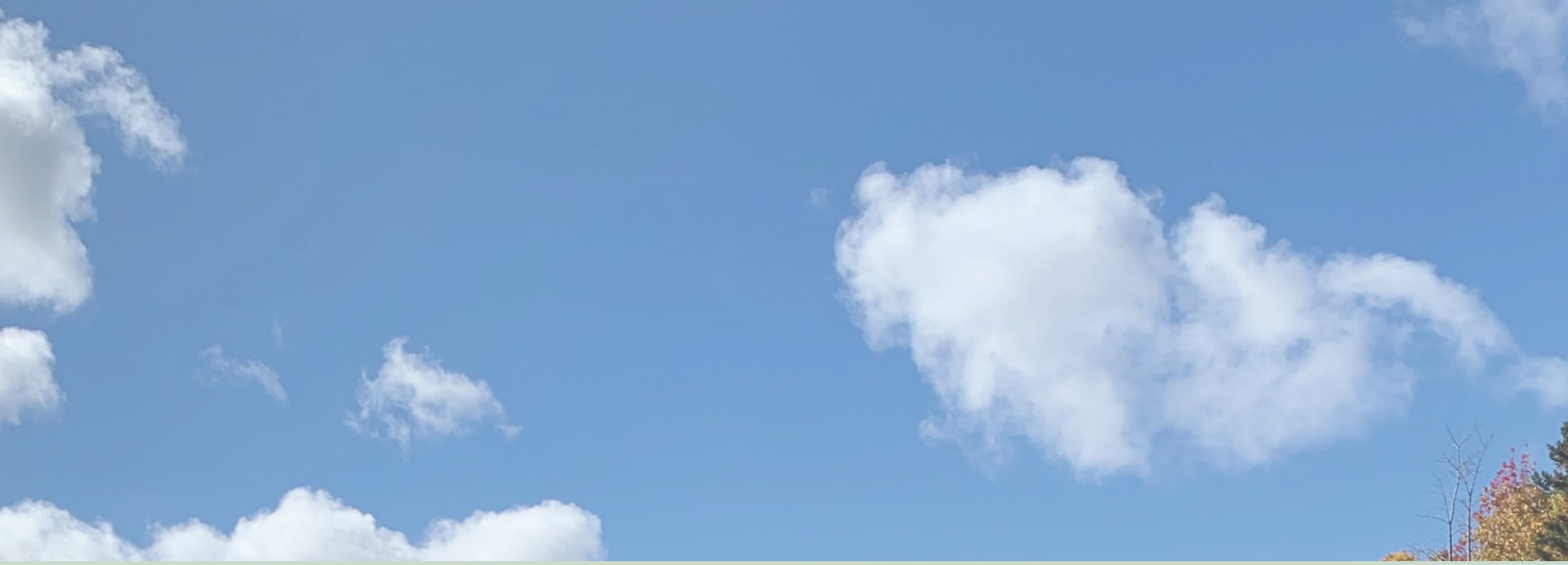

CFRU

2022 Annual Report

Cooperative Forestry Research Unit

CFRU

Cover illustration from left to right:

C: A visualization of a LiDAR data set acquired in summer 2021 with NASA's G-LiHT instrument in the Penobscot Experimental Forest, Bradley, Maine. F: Members snowshoe to scout a MASN sight off of the Golden Road, photo: Eric McPherson (CFRU). R: Aaron Weiskittel and Bob Seymour tour CFRU members around the Demeritt Forest, showing off impressive results of a white pine shelterwood treatment. U: A smooth barked American beech perfectly marked by a black bear likely hunting for beechnuts. Photo above: South Branch Pond, Baxter State Park. All photos other than those specifically credited by Regina Smith, CFRU.

Cooperative Forestry Research Unit

2022 Annual Report

Edited by Regina Smith

Founded in 1975, the Cooperative Forestry Research Unit (CFRU) is one of the oldest industry/university forest research cooperatives in the United States. We are composed of 35 member organizations including private and public forest landowners, wood processors, conservation organizations, and other private contributors. Research by the CFRU seeks to solve the most important problems facing the managers of Maine's forests. The CFRU is a core research program of the Center for Research on Sustainable Forests at the University of Maine.

The CFRU is an applied scientific research organization. As scientists, we favor metric units (e.g., cubic meters, hectares) in our research; however, the nature of our natural resources business frequently dictates the use of traditional North American forest mensuration English units (e.g., cubic feet, cords, acres). We use both metric and English units in this report. Please consult any of the conversion tables that are available on the internet if you need assistance.

Citation: Smith, R. K., (Ed) 2022. Cooperative Forestry Research Unit: 2022 Annual Report. Center for Research on Sustainable Forestry, University of Maine. Orono, ME. 45 p

Cooperative Forestry Research Unit

A Core Program of the Center for Research on Sustainable Forests

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crsf.umaine.edu

CFRU YouTube Page

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Director's Report

The Cooperative Forestry Research Unit nears one year closer to its critical 50th anniversary, which is a tremendous milestone for such an important yet dynamic organization. Of course, this past year was not without its own unique opportunities that required both collaborative and creative problem-solving. The key is the CFRU remains intact and vibrant as ever, which I believe is highlighted in this annual report.

I would like to mention a few of these unique opportunities from the past year just to showcase the CFRU member continued commitment and support for the organization. The CFRU started the year under the direction of University of Maine at Fort Kent's Dr. Neil Thompson, which was a new era for the organization in not being directed by a University of Maine faculty member. Neil was fully engaged and working hard to help transition the CFRU to a new research portfolio given recent faculty hires at the University of Maine. Unfortunately, the University of Maine System's fiscal challenges from the global pandemic and recent changes in the faculty at the University of Maine at Fort Kent, Neil decided he need to focus his efforts on the forestry program there. We appreciate Neil's willingness to take on the CFRU and help us to bridge things.

In the past, CFRU has been lead by university faculty members with certain academic backgrounds and credentials. With unanimous support of the CFRU Executive Committee, a new position (CFRU Program Manager) was quickly created and approved, which was offered to the current CFRU Communications and Research Coordinator, Regina Smith. For the past year, Regina has done an incredible job with CFRU communications and has fully embraced this new role with an August 1 start date. Regina's leadership represents a new era for the CFRU and its importance as a milestone for the organization that can not be underscored enough. Not only is this the first time that CFRU has been led by a non-university faculty member, but the very first time the CFRU has been led by a female. I am fully delighted to continue to work with Regina and support her efforts to move the CFRU forward.

Finally, CFRU is an unique organization that operates within the University of Maine System, which offers numerous direct and indirect benefits to our membership. One key challenge is that the CFRU has had its own fiscal year (October to September) since its inception, whereas the university operates with a different fiscal year (July to June). This has created endless challenges as we tried to reconcile CFRU accounts with university accountants and a strategic decision was made to streamline the CFRU fiscal year with the university in this past year. We are grateful for the dedication and organizational abilities of CFRU's Financial Manager, Leslee Canty-Noles, who managed the fiscal year transition and did it all with grace. Of course, there is never an ideal time to transition fiscal years, but it is behind us and should simplify things with the university as we move forward.

In terms of the actual research, the CFRU maintains a strong yet diverse portfolio of projects as outlined in this annual report. These projects continue to leverage both internal and external University of Maine resources, while addressing critical knowledge gaps and needs identified by our broad membership. I applaud the researchers, technicians, professional staff, and most importantly, the students themselves, who make this great work possible and so relevant. An important aspect of maintaining this relevance is trying to get in front of potential research needs. As part of her new duties as Program Manager, Regina has already started working on the next CFRU strategic prospectus that highlights and prioritizes membership needs. This past fall, Regina prepared and analyzed a membership research survey, which was used to guide a highly interactive and informative CFRU member listening session on October 18, 2022, which was followed by a successful advisory board meeting and field tour to the long-term research site, Weymouth Point.

I would like to take this time to thank both the CFRU's wonderful staff and membership, both old and new, that helps to make this all happen. We are excited to move the CFRU into its 47th year of existence with your support and involvement.

Sincerely,

Dr. Aaron Weiskittel
Director, Center for Research on Sustainable Forests

Chair's Report

I am very pleased to present this year's Annual Report to the CFRU membership. With all the challenges faced over the past few years, it's fantastic to say that the CFRU's continued commitment to forestry research in Maine remains strong and unwavering as the program approaches its 50-year anniversary in 2025. Six new research projects with a wide range of topics from remeasuring long-term research areas such as Weymouth Point to using emerging technologies such as eDNA for biodiversity and rare species monitoring, were approved for funding in 2022.

I would like to thank Dr. Aaron Weiskittel who continues to wear many hats in championing the CFRU as a core research component of the University of Maine's Center for Research on Sustainable Forests, and his willingness to take on the Interim Program Leader role once again as we faced another staffing challenge.

From Regina Smith's start in March 2021 as the CFRU Research and Outreach Coordinator, to her new role as the CFRU Program Manager, her drive, passion, and effort continues to be instrumental in keeping the CFRU membership engaged and informed on multiple levels. From reinvigorating in-person (and hybrid) Advisory Meetings and Field Tours, to recruiting new members and setting up listening sessions with scientists, Regina's communications efforts have involved numerous e-mail updates, newsletters, field tours, webinars, and several informational videos. I look forward to her keeping this momentum going!

I also want to recognize and thank Leslee Canty-Noyes and Meg Fergusson and their commitment and dedication that ensures CFRU's continued success. Their efforts have not gone unnoticed in the light of challenges and changes that have taken place over the past few years. I would also like to thank Dr. Neil Thompson, for his time as the CFRU Program Leader. Although his time in this role was brief, his passion for teaching and research in forestry, is highly evident, and I look forward to his continued contributions to the CFRU and wish him much success as he works towards strengthening the forestry program at Fort Kent.

I would also like to thank all the scientists, research assistants, and students for their research and continued engagement with the CFRU. This annual report contains 8 progress reports and 2 final reports that speak to the array of research they have carried out in the last year. The CFRU continues to fund our long-term projects critical to the CFRU members and their operations: the silvicultural research network, MASN and the Spruce Budworm L2 Monitoring Program that established the University of Maine Spruce Budworm Lab. Additionally, the CFRU led the effort in compiling and formatting updates to the 2016 Spruce Budworm Task Force Executive Summary, a guiding document that is intended to help guide the next several years of new research priorities related to budworm and the Early Intervention Strategy.

I would also like to highlight that 2022 was a year of growth for the CFRU family: Pleasant River Lumber Co. joined the CFRU membership which represents approximately 8.6 million acres of Maine's roughly 17 million acres of forests.

I would also like to thank Ian Prior for his past service as the CFRU Chair, and to echo his encouragement from his 2021 Chair Report for all CFRU members to remain engaged, it is your input that helps guide the CFRU and the research it supports.

Lastly, I would like to issue a challenge to the CFRU membership. With the growing emphasis on how forests can help mitigate climate change and meet carbon sequestration goals, we have an opportunity and a need to add additional long-term research sites across the state to the Maine's Adaptive Silviculture Network (MASN). Let's work together in identifying additional sites!

Sincerely,

Eugene R. Mahar

Eugene Mahar
Chair, Cooperative Forestry Research Unit

Program Manager's Report

It is with great pride that I introduce the 2022 CFRU Annual Report. In years prior, I was responsible for this report from a communications perspective, making sure typos were caught and numbers were reported accurately. Though I continue to design and format communications and reports such as this one, my relationship to them has changed. In August 2022, with unanimous support from our Executive Committee, I transitioned into my new role as Program Manager of the Cooperative Forestry Research Unit. Crafting this year's annual report has given me the time and perspective to pause and observe my role here. Above all, my most important responsibility is to support our members by supporting the scientists who help drive our cooperative's research mission. My deepest thanks go out to our advisory committee for staying engaged and collaborating with our funded researchers. Completed CFRU research projects are that much more impactful when we are able to take it off of the shelf, out of the journal, and put it to the test in forest operations. To our funded researchers, thank you for your willingness to dedicate your time and resources to helping our industry answer our many questions about what forest management looks like from an informed research perspective. I'd also like to thank my CFRU and CRSF team: Leslee Canty-Noyes, Meg Fergusson, Eric McPherson, and Aaron Weiskittel. For an office whose staff can be counted on one hand, we have accomplished so much together and I would not have made it this far without your encouragement, assistance, and insights.

I have come to appreciate the many scales that CFRU research spans. Take the scale of time for instance. With some of our long-term projects, such as Maine's Adaptive Silvicultural Network, the forests will take time to respond to research treatments. It will take time to quantify what the responses on the landscape mean for management. Aaron often quotes an adage that goes something like: "*We wouldn't call it research if we knew what the outcomes would be*". With good design in mind and practice, we patiently await MASN outcomes as we continue to remeasure and install new sites. Some of our funded projects have shorter turnaround windows for results that have big implications for current and future management scenarios. For example, the Northern Conifer Silviculture Guide will help address some climactic operational challenges foresters are facing on the ground today.

When thinking about the Spruce Budworm Lab, the scale of size comes to mind. This year I was able to spend some time with Lab Manager James Stewart, following him around as he processed balsam fir branch samples to look for any overwintering spruce budworm larvae (L2). The CFRU represents a combined 8.6 million acres of forestland, yet the lab's scale is highly local, looking for 7 L2s per branch/site as a critical threshold, beyond which, the propensity for defoliation is certain. Our members are fortunate to have access to this essential forest health monitoring service and we're excited to see what the lab comes up with next for research ideas.

Wheatland's Enhanced Forest Inventory (EFI) project represents the scale of space, utilizing Airborne Laser Scanning and NASA campaigns that provide detailed sample areas of Maine's forests with high-resolution, research-grade data. In their final year of funding, we are excited to see what their design results mean for future EFIs in Maine.

When I look through our portfolio of research projects and the scales they span, I feel confident that we are doing our best to anticipate forestry challenges of all sizes and shapes and respond meaningfully with methods grounded in research.

Many people have helped get me to where I am today, where the CFRU is today, and I would be remiss if I didn't take the time to highlight my shared milestone with this organization: I am the first woman to lead the CFRU. My excitement about this accomplishment is mixed with a deep motivation to continuously strive for better representation of all types in our industry. I encourage us all to ask who isn't at the table and to chip away at the systemic barriers that keep those seats out of reach. Let's do this work together.

Best,

Regina Smith

Regina Smith (she/her)
Program Manager, Cooperative Forestry Research Unit

Staff

Regina Smith, Program Manager, Cooperative Forestry Research Unit
Aaron Weiskittel, Director, Center for Research on Sustainable Forests
Leslee Canty-Noyes, CFRU/CRSF Administrative Specialist
Meg Fergusson, CRSF Outreach and Communications Specialist
Eric McPherson, CFRU Intern

CFRU Membership

Forest Landowners & Managers

Acadian Timber
Appalachian Mountain Club
Baskahegan Company
Baxter State Park, SFMA
BBC Land, LLC
Clayton Lake Woodlands Holdings, LLC
Downeast Lakes Land Trust
EMC Holdings, LLC
Fallen Timber, LLC
Fresh Timber, LLC
Frontier Forest, LLC
Irving Woodlands, LLC
Maine Bureau of Parks & Public Lands
Maine Forest Service
Maine Inland Fisheries & Wildlife
Manulife Investment Management
Mosquito, LLC
New England Forestry Foundation
Pleasant River Lumber Co.
Prentiss and Carlisle Company, Inc.
Presley Woods, LLC
Robbins Lumber Company
Sandy Gray Forest, LLC
Seven Islands Land Company
Solifor Timberland Inc.
Sylvan Timberlands, LLC
The Conservation Fund
The Nature Conservancy
Tree-Star Timberlands
Wagner Forest Management
Weyerhaeuser

Wood Processors

Sappi North America

Corporate & Individuals

Acadia Forestry, LLC
David B. Field
Forest Society of Maine
The Forestland Group
Huber Engineered Woods, LLC
LandVest
Si Balch

Executive Committee

Chair: **Eugene Mahar,** LandVest *(Frontier Forest, LLC; Clayton Lake Woodlands Holding, LLC; EMC Holdings, LLC, Mosquito, LLC, Fresh Timber, LLC)*

Vice Chair: **Steve Tatko**, Appalachian Mountain Club

Treasurer: **Ian Prior,** Seven Islands Land Company

Member-at-large: **Jeremey Miller,** American Forest Management *(BBC Lands)*

Advisory Committee

John Ackley, Weyerhaeuser
Kyle Burdick, Baskahegan Company
Ernest Carle, Downeast Lakes Land Trust
Ked Coffin, Irving Woodlands, LLC
Dave Dow, Prentiss and Carlisle Company, Inc.
Alec Giffen, New England Forestry Foundation
Mike Jurgiewich, Wagner Forest Management
Allison Kanoti, Maine Forest Service
Laura Kenefic, U.S. Forest Service
Al Lyons, Manulife Investment Management
Craig McLaughlin, Maine Department of Inland Fisheries & Wildlife
Jake Metzler, Forest Society of Maine
Bill Patterson, Maine Bureau of Parks & Public Lands
Gaetan Pelletier, Northern Hardwoods Research Institute
Dan Pelletier, Huber Engineered Woods, LLC
Stephen Pollis, Tree-Star Timberlands
Ian Prior, Seven Islands Land Company
James Robbins, Robbins Lumber Company
Brian Schneider, The Conservation Fund
Dan Smith, Pleasant River Lumber Co.
Chris Stone, The Nature Conservancy
Nava Tabak, Baxter State Park, SFMA
Kevin Topolniski, Acadian Timber Corp.
Nate Vir, Sappi North America

Research Scientists

Colby Brungard (PhD), Environmental Soil Consulting
Hamish Greig (PhD), University of Maine
Anthony Guay (MS), University of Maine
John Gunn (PhD), Spatial Informatics Group
John Hagan (PhD), Our Climate Common
Daniel Hayes (PhD), University of Maine
Chris Hennigar (PhD), FORUS Research
Keith Kanoti (MS), University of Maine
Laura Kenefic (PhD), U.S. Forest Service
Claire Kiedrowski (BS), Maine Library of Geographic Info.
Kasey Legaard (PhD), University of Maine
Peter McKinley (PhD), The Wilderness Society
Angela Mech (PhD), University of Maine
Nicole Rogers (PhD), University of Maine
David Sandilands (MS), University of Maine
Robert Seymour (PhD), University of Maine
Erin Simons-Legaard (PhD), University of Maine
James Stewart (BS), University of Maine
Neil Thompson (PhD), University of Maine at Fort Kent
Aaron Weiskittel (PhD), University of Maine

External Research Staff

Ken Bundy, Machine Learning Research Consultant, UMaine
Nicholas Butler, Natural Resources Conservation Service
Joshua Dera, Natural Resources Conservation Service
Alaina Kresovic, Natural Resources Conservation Service
Larry Whitsel, Computer Science Faculty, UMaine

Undergraduate Students

Andrew Boutin (BS), School of Forest Resources, UMaine
Rissa Currie (BS), School of Forest Resources, UMaine
Becca Cusick (BS), UMaine

Graduate Students

Kelsi Anderson (MS), University of New Hampshire
Kirstin Fagan (MS, PhD in progress), UMaine
Jasmine Gregory (MS), School of Forest Resources, UMaine
Jamin Johanson (PhD), School of Forest Resrouces, UMaine
Jonah Levy (PhD), Tufts University
Jacob Pliskaner (MF), School of Forest Resources, UMaine
Stephanie Willsey (MS), School of Forest Resources, UMaine

Partners/Stakeholders/Collaborators

Acadian Timberlands Corp.
Appalachian Mountain Club
Baskahegan Company
Baxter State Park
Forest Society of Maine
Huber Forest Resources
Huber Resources Corporation
J.D. Irving Limited
Landvest
Maine Bureau of Parks and Lands
Maine Department of Environmental Protection
Maine Department of Inland Fisheries and Wildlife
Maine Department of Transportation
Maine Forest Service
Maine Library of Geographic Information
Maine Natural Areas Program
NASA Goddard Spaceflight Center
New England Forestry Foundation
New Hampshire Division of Forests and Lands
NOAA Office for Coastal Management
Northern Forest Conservation Services, LLC
Passamaquoddy Forestry Department
Penobscot Nation, Department of Natural Resources
Rangeley Lakes Heritage Trust
Seven Islands Land Company
Stephen Phillips Memorial Preserve Trust
The Nature Conservancy
U.S. Fish and Wildlife Service, Umbagog
U.S. Forest Service, National Forest System, Enterprise
U.S. Forest Service, White Mountain National Forest
U.S. Forest Sevice, Northern Research Station FIA Program
University Forests, University of Maine
University of Maine Advanced Computing Group
Vermont Department of Forests, Parks, and Recreation
Vermont Land Trust
Wagner Forest Management
Weyerhaeuser

Financial Report

In FY 2022, the Cooperative Forestry Research Unit had 36 members, representing just over 8.5 million acres of Maine forestland. Our sole wood processor, Sappi North America of Maine, processed just over 2 million tons of wood. Pleasant River Lumber Company is the CFRU's newest member and is being represented on the advisory committe by Dan Smith. Pleasant River Lumber Company is a landowner and has 5 mills throughout the state, operating in Jackman, Dover, Enfield, Hancock, and Sanford. We would like to extend a warm welcome to our new member and express our gratitude to our cooperators who continue to financially support the research mission of the CFRU.

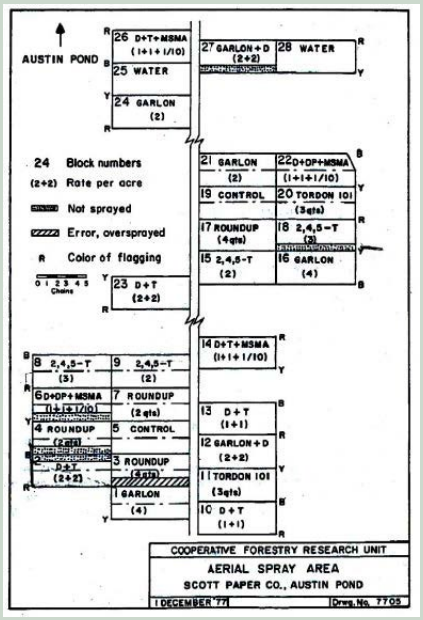
CFRU Member	FY21-22
FOREST LANDOWNERS/MANAGERS:	
Irving Woodlands, LLC	$69,820.00
BBC Land, LLC	$54,529.00
Weyerhaeuser	$47,044.00
Wagner Forest Management	$45,043.00
Clayton Lake Woodlands Holdings, LLC	$44,363.00
Seven Islands Land Company	$41,957.00
Prentiss and Carlisle Company, Inc.	$41,955.00
Maine Bureau of Parks & Public Lands	$25,229.00
Katahdin Forest Management, LLC	$17,522.00
Fallen Timber, LLC	$13,028.00
Fresh Timber, LLC	$12,444.00
Solifor Timberland Inc.	$9,991.00
The Nature Conservancy	$9,269.00
Baskahegan Company	$8,300.00
Sandy Gray Forest, LLC	$5,841.00
Sylvan Timberlands, LLC	$5,285.90
The Conservation Fund	$5,515.00
Tree-Star Timberlands	$5,373.00
Appalachian Mountain Club	$4,315.00
Downeast Lakes Land Trust	$3,266.00
Frontier Forest, LLC	$3,115.00
EMC Holdings, LLC	$2,363.00
Baxter State Park, SFMA	$1,725.00
Robbins Lumber Company	$1,564.00
Presley Woods, LLC	$1,397.00
Mosquito, LLC	$1,000.00
New England Forestry Foundation	$259.00
Manulife	$0.00
TOTAL	**$481,512.90**
WOOD PROCESSORS:	
SAPPI Fine Paper	$25,556.91
TOTAL	**$25,556.91**
CORPORATE & INDIVIDUAL MEMBERS:	
Huber Engineered Woods, LLC	$1,000.00
Forest Society of Maine	$1,000.00
Si Balch	$0.00
LandVest	$200.00
David B. Field	$100.00
Acadia Forestry, LLC	$100.00
TOTAL	**$2,400.00**
GRAND TOTAL	**$509,469.81**

Expenses Incurred FY 2022

Perhaps the most important financial update to report for the CFRU is the change in the fiscal calendar. FY2022 was a short one, running from October 2021 - June 2022. Our new fiscal year will run from June 2022 - July 2023 in order to be more aligned with the Center for Research on Sustainable Forests and the University of Maine. Projects in this report therefore cover a shorter timeline than most years, but this will even out in next year's annual report.

Project Expenses as of June 30, 2022			
PROJECT	**Principal Investigator**	**Approved Amount**	**Amount Spent To-Date**
Total Administration		**$208,889.00**	$153,280.97
Administration	Smith	$208,889.00	$153,280.97
Research Projects			
Silviculture and Productivity:		$245,591.61	$31,537.73
Maine's Adaptive Silviculture Experimental Network (MASEN)	Smith	$81,267.35	$21,698.05
Beech bark disease 40-year results	Kenefic/Livingston	$1,650.00	$999.88
Silvicultural Guide	Kenefic	$21,209.00	$5,461.18
Small Diameter Tree Harvest	Kizha	$3,387.98	$3,378.62
Spruce Budworm Lab	Mech	$138,077.28	$57,799.29
Growth & Yield Modeling		$163,136.62	$59,545.57
Interdisciplinary spatial modeling-new tools for forest management	Johanson	$36,260.00	$10,000.00
Mapping Forest Products	Hayes	$82,162.62	$49,545.57
Maine High Resolution Land Cover and Forest Type Data for the State of Maine	Legaard	$25,000.00	$13,171.95
Forest Carbon and Timber Potential for Northern Maine's Working Forests	Daigneault	$19,714.00	$9,476.34
Wildlife Habitat		$70,659.57	$2,750.00
Watershed-scale drivers of temperature and flow of headwater streams in Northern Maine	N. Thompson	$6,664.57	$2,750.00
Changes in Forest Practices and Bird Populations in Maine's Commercial Forest:1992-2022	Hagan	$50,000.00	$50,000.00
American Marten:Forest Vertebrate Umbrella Species	Simons-Legaard	$13,995.00	$8,706.82
		Begin Balance	**Revenue - Expenses**
Fleet Account	Smith	$60,759.03	$19,976.25
CAFS 3 @ 23%	Weiskittel	$425,000.00	$143,511.93

CFRU Field Tours in 2022



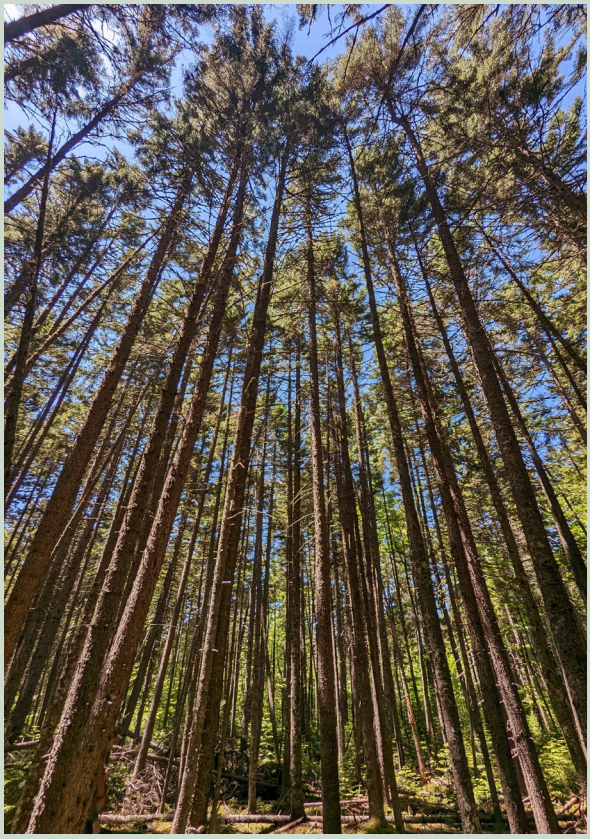
SAF & CFRU Tour Austin Pond

In July 2022, Maine SAF and CFRU co-hosted a field tour at Austin Pond Study Area (APSA) in July 2022. Austin Pond is a long-term CFRU study dating back to the 1970s that focused on trialing available herbicides at the time, and was followed in later years with precommercial thinning trials. We were joined by former CFRU Program Leader, Dr. Robert Wagner (Purdue University). During Dr. Wagner's time with the CFRU, results from APSA and the effectiveness of pairing PCT and herbicide release for softwood were emerging. 40 years after the intial study was implemented, results pointed to utilizing both treatments for maximizing the merchantable volume of a stand. Weyerhaeuser now owns the land that APSA sits on, and while they have moved on as a company from using some of the herbicides once applied by the former Scott Paper Co. ownership, they are committed to keeping site as a long-term study. Other presenters included Cullen Utermark, Weyerhaeuser forester, who provided a field demo and Q&A on drone applications for practicing foresters, and Dave Maass, 2022 SAF Fellow & consulting forester, focused on larch species-site trials in Maine that were started in the 1980s by Scott Paper Co. Some of his most recent findings can be found on NEFIS, North East Forestry Information Source.

CFRU & Acadian Timber Co. Host Fall Field Tour at Weymouth Point

Weymouth Point (WPSA), a long-term CFRU study, was established in 1979 to determine the potential effects of mechanized whole-tree harvesting methods. Up until whole-tree harvesting (WTH), branches and tree tops were left on site to decompose. Concerns at the time were growing about how the emerging practice could influence future site productivity through soil nutrient depletion. Weymouth Point sought to address concerns over nutrient depletion of WTH by focusing on the spruce-fir forests of north-central Maine, situated on a pair of adjacent watersheds. The site continues to be measured, nearly 45 years later, for invaluable data on the topic and is well situated for future research potential.

In October 2022, we were joined for our fall field tour by one of WPSA's original researchers, Dr. Tat Smith, Professor and Dean Emeritus of Forestry, University of Toronto. His presentation focused on the past treatments that WPSA received and what we know up to this point about quanitifying nutrient losses after various harvest removal methods. To date, there is no evidence whole-tree harvesting negatively affected future tree growth or soil nutrient contents. Forest floor sampling conducted in 2014 did indicate a slight reduction in carbon stocks 35 years post harvest. WPSA continues to be remeasured by CFRU crews and we have worked closely with the landowner to discuss next steps in research treatments. Steph Willsey, a MS student in the School of Forest Resources at UMO, gave an overview of NAIP vs. LiDAR for enhanced forest inventories (EFIs) for practioners. She is a student with Wheatland Geospatial Lab and they are working with CFRU on affordable EFI solutions. Their research is looking at plot design, shape, sampling size/intensity, and other variables to try and find a sweet spot for practioners hoping to conduct EFIs in a cost-effective way.



Above: Kevin Topolniski, Chief Forester, Acadian Timber Co. Photos top to bottom: Dr. Tat Smith presenting WPSA's history. Reference stand/watershed (N. Thompson, UMFK). Aaron Weiskittel & Steph Willsey give an overview of pros and cons of NAIP vs. LiDAR to forest practioners.

A New Northern Conifer Silviculture Guide

Progress Report

Laura Kenefic, Research Forester, U.S. Forest Service
Keith Kanoti, University Forest Manager, University of Maine
Robert Seymour, Professor Emeritus of Silviculture, University of Maine
Nicole Rogers, Assistant Professor of Silviculture, University of Maine

Abstract

The current silviculture guide for the northern conifer forest type (i.e., spruce – fir and associated species) in the Northeast is close to 50 years old with little relevance to conditions and challenges facing forest managers today. This project is remedying that problem by synthesizing and interpreting an additional half-century of research to develop scientifically robust silvicultural recommendations to meet contemporary forest management needs. Work began in October 2021 to conceptualize the format, decide on the information to be included, consult with an advisory panel of stakeholders to ensure applicability of the approach, and draft sections of text. Writing, data synthesis, and creation of figures is underway and will continue through Fall 2022. In 2023, a new silviculture guide for northern conifers based on the best available science will be published by the U.S. Forest Service, a professionally produced companion video will be released, and a field workshop for CFRU members and others will be held.

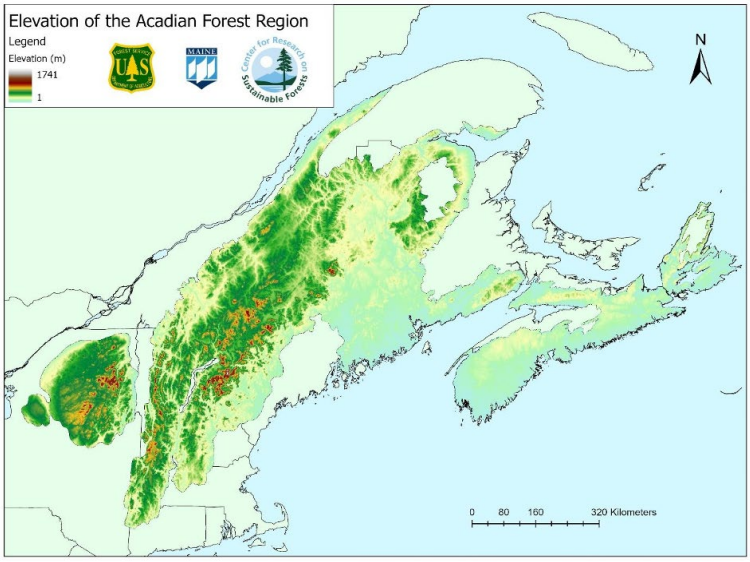


Figure 1. Topographic map showing the extent of the northern conifer forest type

Approach

- Complete literature review and draft table of contents (Table 1, page 16).
- Invite additional cooperators to the advisory panel. Convene advisory panel to review and make recommendations for revision of the contents of the guide and video at key steps in the development process.
- Gather unpublished data or research results from cooperators and/or extract data from long-term experiments to fill information gaps. Use these to update supporting materials such as growth and yield tables.
- Write the draft guide and draft the content of the companion video. Undertake workshop planning and logistics.
- Finalize the guide and video based on feedback from advisory panel. Submit these to the U.S. Forest Service and CRSF, respectively, for review, approval, and publication/posting.
- Host workshop for practitioners, and work with communications and public affairs staffs and partners to widely disseminate products.

Project Objectives

- Produce a new Silviculture Guide for Northern Conifers using a process of co-production wherein stakeholders including CFRU members and other public and private forestland owners and managers are engaged in content development.
- Collaborate with partners to disseminate the guide (online and in print) and a professionally produced companion video, and host an in-field workshop for CFRU members and others.

Key Findings

- Developed a new stocking guide for spruce – fir dominated stands; this is the basis for an in-preparation manuscript to be submitted to a refereed journal.
- Convened an advisory panel, including representatives of CFRU member organizations, on March 2, 2022. The draft table of contents was reviewed, and information gaps were identified.
- Presented the revised table of contents in a technical session at the New England Society of American Foresters annual winter meeting on March 23, 2022, with breakout sessions to get feedback from practitioners and identify needs and strategies for the guide.
- Undertook a comprehensive literature review and compiled a reference database to guide the authors.
- Extracted forest inventory data from the U.S. Forest Service and Canadian Forest Service, with data manipulation and summary to quantify condition and extent of the northern conifer forest.
- Allocated sections of the Guide to the writing team and invited contributing authors. Many sections have been drafted and reviewed by the writing team.

Photos 1 & 2. Some of the writing team (Laura Kenefic, Nicole Rogers, Bob Seymour) at work discussing silvicultural approaches in the northern conifer forest.

Future Plans

Writing team will attend a two-day field tour of Umbagog National Wildlife Refuge in July 2022 to learn about their management strategies for wildlife habitat maintenance in red spruce – yellow birch forests; this will be used to write a case study in the guide. Writing of the guide, video production, and planning of the practitioner workshop will continue until all deliverables are finalized.

Acknowledgements

We would like to thank David Ray and Carolyn Ziegra who, in addition to the principal investigators, have been working to develop the information, text, and figures for the guide. Thank you to the many practitioners, including those from CFRU member organizations, who have participated in our advisory panel and working session.

Geographic Location of Project

Maine, New Hampshire, Vermont, New York

Partners / Stakeholders / Collaborators

Acadian Timber
Appalachian Mountain Club
Baskahegan Company
Baxter State Park
Cooperative Forestry Research Unit
Forest Society of Maine
Huber Resources Corporation
J.D. Irving Limited
LandVest
Maine Bureau of Parks and Lands
Maine Forest Service
Maine Department of Inland Fisheries and Wildlife
New England Forestry Foundation
New Hampshire Division of Forests and Lands
Northern Forest Conservation Services, LLC
Passamaquoddy Forestry Department
Penobscot Nation, Department of Natural Resources
Seven Islands Land Company
The Nature Conservancy
U.S. Fish and Wildlife Service, Umbagog National Wildlife Refuge
U.S. Forest Service, Green Mountain National Forest
U.S. Forest Service, National Forest System, Enterprise
U.S. Forest Service, White Mountain National Forest
Vermont Department of Forests, Parks, and Recreation
Vermont Land Trust
Wagner Forest Management

Professional and Student Involvement

	Names	Degree Sought	Time Allocated (CFRU Funds) hrs/week or FTE
Graduate Students	David Ray	Ph.D.	12 hrs/month for 6 months
Undergraduate	Carolyn Ziegra	B.S.	10 hrs/week through May 2022 20 hrs/week through July 2022

Table 1 (left). Draft table of contents: this draft was developed with input from the advisory panel and target users.

Photo (above). Northern Conifer Guide writing team in the field: Carolyn Ziegra, Nicole Rogers, and Laura Kenefic.

All photos provided by the research team.

Control unit in Weymouth Point Study Area. Photo: N. Thompson, UMFK

Revisiting Weymouth Point

Progress Report

Neil Thompson, Assistant Professor of Applied Forestry, University of Maine Fort Kent
Aaron Weiskittel, CRSF Director, University of Maine
Nicole Rogers, Assistant Professor of Silviculture, University of Maine
Regina Smith, CFRU Program Manager

Abstract

The Weymouth Point Study Area (WPSA) was established in 1979 to quantify nutrient removals through whole tree and stem-only logging (1981), nutrient mobilization after herbicide treatment (1985), and the growth of trees with and without precommercial thinning and fertilization (1991). WPSA has been one of CFRU's flagship long-term study areas, and was last measured in 2016. A 42-year measurement in 2023 will provide additional insight on 35-year growth patterns discussed by Smith et al. (2022) and inform a discussion on the next steps for the site in the context of other ongoing spruce/fir silviculture research.

Photo 1. Reference watershed at Weymouth Point Study Area. The stand has not been disturbed since 1903 and is dominated by red spruce. Photo: N. Thompson, UMFK

Project Objectives

- Repeat diameter and height growth at all fixed plots in the WPSA
- Analyze growth response by treatment following up on 35-year measurement
- Assess growth model behavior (e.g. Northeast/Acadian FVS variants)
- Establish a plan for the next stage in treatment/measurements at WPSA

Approach

Weymouth Point is a long-term biomass removal study of unique value to the CFRU and beyond. Dr. Tat Smith and colleagues recently completed an array of detailed measurements to capture the trends 35 years after the initial set of treatments, which have been published in a variety of formats (Preece 2017, Smith et al. 2022a,b). As Weymouth Point is beginning to approach rotation age, questions about its status, value, and future need to be addressed. To better understand the potential opportunities at Weymouth Point, files from Tat Smith have been compiled and harmonized. In addition, a site visit was conducted on June 21, 2022 and led by Dr. Neil Thompson with Acadian Timber personnel (Photo 2). Permanent sample plots re-established by Dr. Tat Smith across the different treatments were visited and protocols discussed. A planned remeasurement of all permanent sample plots would be conducted in the summer of 2023 or 2024 to help prepare for potential treatment options. In particular, the uniqueness and high value of the reference area that has largely remained intact and highly stocked (Figure 1). This area has not been

harvested or severely disturbed since the 1910s, which offers an array of potential research opportunities. Based on projections using the Forest Vegetation Simulator (FVS), all permanent sample plots are expected to continue to linearly accumulate volume over the next two decades including the reference area (Figure 3). A logical follow-on study to the original research is replicating the original treatments including a harvest in the reference area.

Key Findings

The CFRU fall field tour was held at WPSA in October of 2022 (see page x for more details). This event was well attended by our membership and included an overview of Weymouth Point's research history by Dr. Tat Smith, who completed his PhD in the late 1970s on whole-tree harvest at the site. This invaluable perspective was key to a discuss on future plans for WPSA. CFRU personnel has been working to consolidate nearly 50 years of data, related publications, and other materials to be retained for long-term analyses.

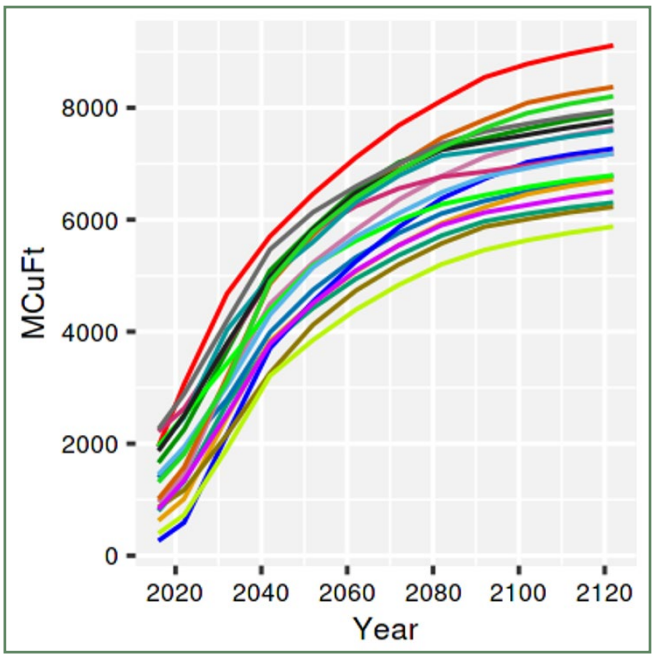


Figure 1. Projections of merchantable volume (ft3 ac-1) over time for the permanent sample plots at Weymouth Point based on their last measurement in 2015.

Future Plans

CFRU field crews will visit Weymouth Point Study Area in the summer of 2023 to conduct forest measurements and remonument trees and plot centers.

Acknowledgements

The CFRU thanks Dr. Tat Smith for his continued involvement in WPSA through member engagement, presentations, and his insights for future harvest plans and considerations. We also thank Acadian Timber Corp. valuing WPSA and its value for long-term research.

Partners / Stakeholders

Acadian Timber Corporation

CFRU personnel, Dan Hayes (UMaine/Wheatland Geospatial Lab) and Acadian Timber Co. summer of 2022

Maine Adaptive Silviculture Network (MASN)

Progress Report

Regina Smith, CFRU Program Manager, University of Maine
Eric McPherson, CFRU Intern, University of Maine
Aaron Weiskittel, CRSF Director, University of Maine

Abstract

The goal of this study is to examine alternative silvicultural approaches for improving rotation length productivity and value of mid-rotation stands in Maine. The main objective of this project will be to establish a network of 18 operational scale study installations distributed across the state in all combinations of mid-rotation softwood, mixedwood, and hardwood stands of good, medium, and low site quality. Once established, this network will serve as a field laboratory, where on an operational scale: 1) silvicultural treatments can be compared, 2) productivity and costs of multiple harvest methods can be quantified, 3) data will inform and improve growth and yield (G&Y) models, 4) predictions of remotely sensed forest inventory attributes and habitat quality can be validated, and 5) the effects of forest management on wildlife habitat can be quantified.

Key Findings/Accomplishments

Before the 2022 field season, the CFRU research team spent time revising the MASN inventory protocol. A number of assessments were added such as coarse woody debris survey, earthworm detection survey, stump and harvester trail survey, beech bark disease assessment, and a field for recording general unique features encountered on the landscape. We hope that anticipating future research needs and including them in the remeasurement protocols will be a benefit for landowners and researchers alike. Achievements in the last year include:

- A new MASN site in Mayfield (Weyerhaeuser) was installed after preharvest inventories were completed, bringing our total number of MASN sites to 8, with a future goal of 18 total installations.
- 3 MASN sites had a full remeasurement cycle completed in the summer of 2022.
- All MASN sites were visited at least once in summer of 2022 to survey for bird species, abundance, and behavior on each treatment block.
- In the spring of 2022, Seven Islands Land Company used prescribed fire on their MASN site in Nashville Plantation with assistance from the Maine Forest Service (photos p. 21). One of the objectives for SILC was to experiment with prescribed fire as an alternative to using herbicide for site preparation. Another benefit of the burn is that nutrients are returned to the soil for the next growth cycle. The fire went as planned and was attended by Commissioner Amanda Beal of the Maine Department of Agriculture, Conservation, and Forestry. The CFRU took soil samples before the burn and plans to return this summer for another round of sampling to quantify the effects of prescribed burns on soils. Our thanks go out to Seven Islands Land Company for their ambitious and alternative ideas for advancing forestry and prescribed fire in Maine.
- CFRU intern Eric McPherson has spent time cleaning data, organizing files, and identifying gaps in the proposed treatment matrix. Additionally, he has produced an ArcStory for members to follow the progress of MASN installations and site summaries.

Future Plans

Currently, the CFRU is in the process of forming a panel consisting of landowners and researchers to better inform the rest of the site installations and operations. There are geographical gaps that remain as well as site composition/quality gaps. A high priority for the rest of the sites that have yet to be installed is making sure we are getting treatment replicates across the matrix of conditions. Ensuring that site replicates are installed will not only attract researchers looking for publishable data in the future, but will also ensure these studies have implications beyond being a local case study. We are currently working with three landowners to identify similar sites and a suite of treatments that are ideal for both the landowners and the replicate matrix we are looking to fill in. Field season plans for the 2023 CFRU summer crew include visiting MASN sites that are up for remeasurement and completing full inventories.

Partners/Stakeholders/Collaborators

We would like to thank the CFRU membership for their continued support of this long-term research network. We would also like to thank the researchers who have utilized our data for current/future projects and who frequently make themselves available to discuss and provide critical input on research design.

Professional and Student Involvement

- Eric McPherson, MF student with the School of Forest Resources
- Sean Seely, MF student with the School of Forest Resources
- Amos Hinkley, BS student with the Department of Wildlife, Conservation, Fisheries, & Biology
- Dominic Mezzadri, BS student with the School of Forest Resources

Geographic Location

State of Maine. A live map of current MASN sites can be found here.

Prescribed burn in Nashville Plantation, May 2022. Photos N. Thompson, UMFK.

Thirty Years of Change in Commercial Management and Implications for Bird Conservation in Maine (1992-2022)

Progress Report

John Hagan, Our Common Climate
John Gunn, Spatial Informatics Group - Natural Assets Lab
Peter McKinley, The Wilderness Society
Michael Reed, Tufts University

Abstract

In 2021 we began the replication of a major study of birds and commercial forestry conducted in the early 1990s in the greater Moosehead Lake region. The replication of this study is relevant because of national-scaled declines in bird populations, and because forestry practices (and therefore bird habitat) have changed significantly since the early 1990s. We are pleased to report that, as of August 5, 2022, all field data required for this study have now been collected. In the 2021 and 2022 field seasons, we sampled a total 422 points for birds in all forest types and age classes using the point count method. We exceeded our goal of at least matching the sample size of the 1990s study (n=387 points). We enjoyed more media success with a radio story on Maine Things Considered that aired on August 12, 2022. The remaining year of the project (2023) will be devoted to analysis of the data, production our reports and manuscripts, and additional outreach, including a birding trail through the commercial forest near Moosehead Lake. We are on track to meet all our goals. For short informational videos and information about the project, visit the project website.

Photo 1. Conducting a productivity survey for nesting birds.

Project Objectives

Priority 1: Determine how changes in forest management in Maine's commercial forest over the last 30 years have affected bird populations, in relation to national-scaled bird conservation goals.

- Objective 1a: using the same bird survey and vegetation sampling methods we used 30 years ago, quantify changes in density and abundance of landbird populations in a one-million-acre (400K ha) section of Maine's commercial forest.
- Objective 1b: compare habitat availability (i.e., forest types) today with availability in the study area from 30 years ago.
- Objective 1c: compare and contrast changes in landbird abundance and diversity in Maine's commercial forest to regional and national bird population trends.

Priority 2: Identify silvicultural practices that could enhance national-scaled bird conservation goals going forward.

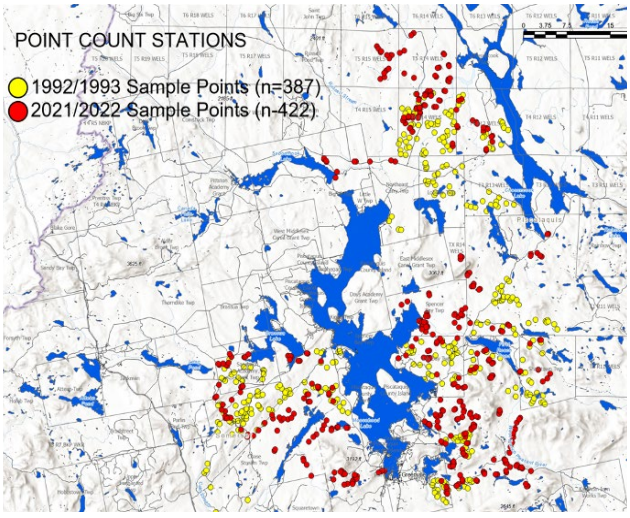


Figure 1. Sample points from 1992/93 and 2021/22 located in the Moosehead Lake region.

- Objective 2a: describe changes in habitat structure as a result of changes in silvicultural practices in the one-million-acre (4-million-ha) study area.
- Objective 2b: as warranted by changes in bird abundance and diversity, identify silvicultural strategies that would "rebalance" bird habitat to achieve both regional and national bird conservation goals as well as future harvest goals of the landowners.
- Objective 2c: bring together all the "birds and forestry" researchers from the Acadian region (Maine, New Brunswick, Nova Scotia) in a day-long virtual symposium to consolidate lessons learned from regional bird research.

Priority 3: Create new opportunities for the birding public to experience the bird conservation benefits of Maine's commercial forest.

- Objective 3a: create a web-based "story map" about the contributions of commercial forests to bird conservation.
- Objective 3b: create a self-guided, roadside birding trail to enhance eco-tourism in Maine's commercial forest.
- Objective 3c: create a short video of both conservation biologists and commercial landowners/managers explaining how forestry contributes to bird conservation at the national scale.

Approach

- Replicate the bird survey sampling intensity of the 1990s study using point count methods (Figure 1).
- Extrapolate species current-day bird species abundances from point count data and stand maps.
- Determine which bird species have increased and which have decreased in our 1-M-acre study area in 30 years.
- Compare species changes in Maine's commercial forest with national-scaled changes.
- Work with landowners to identify forest practice changes that might increase nationally declining species while maintaining or increasing wood supply.
- Create public outreach mechanisms to demonstrate the conservation value of commercial forests, such as a self-guided birding trail near Greenville, and various short videos to be distributed through social media.

Key Findings / Accomplishments

- Completed all field data collection for the study
- Hired a 9-person crew to conduct an ambitious 2022 field season;
- Completed a total of 422 bird point counts in all forest types and age classes between May 23 and July 3, 2022 (ultimate goal was to match the 1990s study of 387 points);
- 422 detailed vegetation surveys at each point count station.
- Downloaded and began evaluation of LiDAR data for describing and predicting bird habitat.
- Started an e-newsletter to keep interested birders apprised of the field season progress.
- Organized workshop for Acadian region's birds-and-forestry researchers, April 7, 2022.
- Produced several short entertaining and informative videos about the project that can be viewed on the project's website in addition to outreach stories featured on Maine Public Radio and the Portland Press Herald.

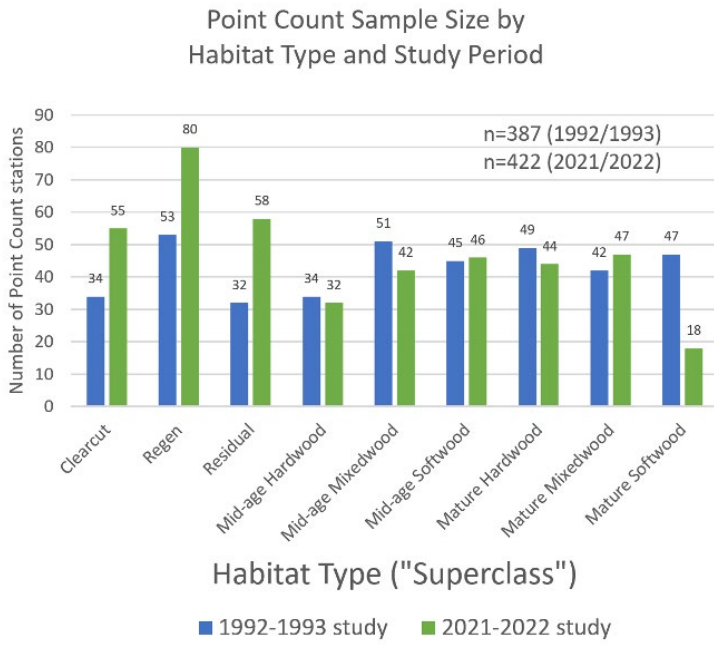


Figure 2. Bird point count sample size by "Superclass" (coarse bird habitat type) for the 1990s and the 2020s study. Our goal was to sample at least 30 point count stations in each Superclass type. Mature Softwood was difficult to find in the 2020s study. "Residual" is a partial cut stand, of which there was an abundance in the 2020s study.

Future Plans

Now that all data are collected, we need to enter and proof approximately 42,000 records of vegetation data in September (2022). For the remainder of calendar 2022, and calendar 2023, we will be completing all project objectives listed above.

Acknowlegdements

We thank Henning Stabins and Weyerhaeuser, Jim O'Malley, Eugene Mahar, and Colton Burgess at Landvest, Trevor London at Huber, and Steve Tatko at AMC. We also thank Dave Sandilands at the Wheatland Remote Sensing Lab for help with LiDAR. We thank our many funders (see below), including the CFRU.

We also thank our hardworking 2022 field crew for many 3:30 AM mornings and long hard days of veg work this past summer: Kelsi Anderson, Ryan Andrews, Jude Dickerson, Josh Kolasch, Jonah Levy, Molly Lynch, Hannah Mirando, Ben Shamgochian, Jaylan Winstanley. We also thank Anna Siegel (Waynflete H.S.) for leading the outreach effort for the project.

Partners / Stakeholders / Collaborators

Steve Tatko, Appalachian Mountain Club
Colton Burgess, LandVest
Weyerhaeuser
Huber Forest Resources

Professional and Student Involvement

Jonah Levy, PhD Student, Tufts University
Kelsi Anderson, MS Student, University of New Hampshire

Photos left to right: 1. Setting up for a veg survey in a Jack Pine plantation. 2. Understory vegetation survey: 2x50 m strip transect. 3. Measuring in 10x50 m veg plot. 4. Conducting a bird point count. All photos provided by the research team.

American Marten: Refining the Umbrella Species Concept in Maine

Progress Report

Erin Simons-Legaard, Assistant Research Professor in Forest Landscape Modeling, University of Maine
Kirstin Fagan, Graduate Research Assistant, Wildlife Ecology, University of Maine

Abstract

The umbrella species concept was proposed as a way to use single species habitat requirements, typically a larger-bodied habitat specialist species with large area requirements, as a guide for ecosystem management. Although intuitively appealing the umbrella species concept is not without criticism, particularly when the efficacy of a prospective umbrella has not been tested. The American marten has previously shown promise an umbrella species in Maine based on potential habitat overlap with other species, but the degree to which the presence of marten is associated with, for example, increased species richness on-the-ground has not been rigorously evaluated. This project builds on a legacy of CFRU-funded projects that have resulted in the development of a long-term dataset of marten occurrence in central Maine. We will compile biodiversity information collected using remote technologies (camera traps and acoustic monitors) and compare patterns of species occurrence and richness with marten use intensity. Results from this project will provide a detailed accounting of the vertebrates covered by the "umbrella" of marten habitat conservation.

Project Objectives

The goal of this project is to revisit and refine the role of American marten as an umbrella species for mature forest vertebrates in the Northern Forest Region. Supporting objectives are to:

- Use long-term live-trapping data collected in our study area (T5 R11 WELS and T4 R11 WELS) to develop a stratified grid system (high, medium, low marten use) for biodiversity sampling.
- Use camera trap data collected in 2019 to identify patterns of mammal occurrence with the stratified grid.
- Deploy acoustic monitors within grid strata to identify patterns of bird occurrence.
- Evaluate associations between marten occurrence and metrics of biodiversity (e.g., species richness).

Approach

- Acoustic monitors will be deployed across a sampling grid (cell size based on average home range size for a female marten in Maine) in T5 R11 WELS and T4 R11 WELS. This grid was previously established in 2019 for camera trapping and is aligned with the long-term network of live traps used to document marten habitat use and selection in previous CFRU-funded projects.
- Monitors will be set to record at dawn and dusk for 2-hours and left in place for approximately 10-days.
- Software will be used to facilitate the development of a songbird species list at each deployment location across the grid, based on song recordings.

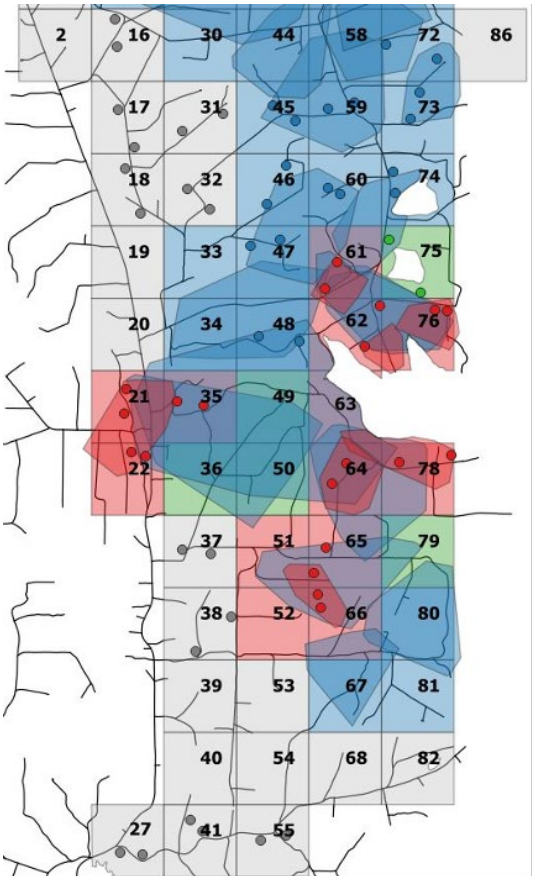


Figure 2. Deployment sites for acoustic monitors (dots) were distributed across grid cells with known use history by American marten based on home range occurance 2019 (polygons). Sites include areas used by both females and males (red), males only (blue), no marten (gray).

- Songbird data will be combined with information about mammal presence, determined from 2019 camera trapping data (Figure 2), to identify species with high co-occurrence with marten and to evaluate relationships between marten use intensity and species richness (total and per taxonomic group).
- Spatial patterns of species richness and relative abundance will also be compared to available maps of forest composition and structure, developed using Sentinel satellite imagery and LiDAR data from 2017 acquisition for statewide mapping.

Key Findings

- Between May and August 2022 we deployed acoustic monitors at 60 sites distributed across 30 grid cells (2 sites per cell).
- Sampled grid cells were selected to represent areas with known use history by marten based on home range occurrence ca. 2019 (Figure 2), including both female and male presence (n=10), male-only (n=10), no marten (n=10).

Future Plans

- In Year 2 we will be compiling species list for each sampled grid cell based on acoustic recordings (birds) and camera traps (mammals).
- Species list will be used to identify species with high co-occurrence with marten and to evaluate relationships between marten use intensity and species richness (total and per taxonomic group).

Student Involvement

Kirstin Fagan, PhD student

Geographic Location of Project

T5 R11 WELS, T4 R11 WELS, Maine

Partners / Stakeholders / Collaborators

Kevin Topolniski, Acadian Timber Corp.

Chris Stone, The Nature Conservancy

Figure 1. Left to right. Example images of species captured at baited camera traps during the 2019 spring field season, close up of American Marten. Photos K. Fagan, UMO.

Watershed Scale Drivers of Temperature and Flow of Headwater Streams in Northern Maine

Final Report

Neil Thompson, Professor of Forestry, University of Maine Fort Kent
Hamish Greig, Associate Professor of Stream Ecology, University of Maine

Abstract

Stream temperature loggers were deployed in randomly selected first and second order streams in northern Maine for the purpose of developing a predictive model of summer temperature regimes. Sample size was 85 in 2019 and 180 in 2020 and 2021. High waters in Fall 2021 and Spring 2022 delayed the retrieval of approximately half of these sensors. Retrieval is in progress and expected Fall 2022, which will permit data analysis, submission of a final CFRU report, and publication. The Smith Brook watershed study initiated under this funding is also delayed by road construction logistics, with forest operations currently expected to begin in 2023. This delay has facilitated an externally funded effort to develop a baseline of stream geomorphology measurements and maps in collaboration with Dr. Sean Smith at UMaine. LiDAR data from 2019 are now available to support all aspects of this project.

Project Objectives

- Establish a network of stream temperature loggers in Aroostook and northern Penobscot, Piscataquis, and Somerset Counties to predict temperature regimes of 1st and 2nd order streams within the study area
- Investigate the influence of forest management on stream temperature and flow utilizing a triplet of watersheds (~1,600 acres each), holding one in reserve and operating on the other two at higher and lower intensity ends of the range of normal management activities

Approach

Temperature loggers (n=85 2019, n=180 2020 & 2021) have been placed in randomly selected 1st and 2nd order streams within in the study area. Metrics, such as average daily maximum stream temperature, will be used as dependent variables in models with predictors such as stream gradient, watershed size, elevation, harvest level, area in lakes and ponds, beaver dams, etc. LiDAR data are now available for the full study area and will be used to calculate metrics representing canopy cover within the watershed and within the riparian area. Temperature loggers have been placed at intervals in each of the three Smith Brook tributaries. The initial 2019 layout has been replaced and enhanced with a greater number of strongly anchored, higher-capacity loggers that will remain in place and record data through the

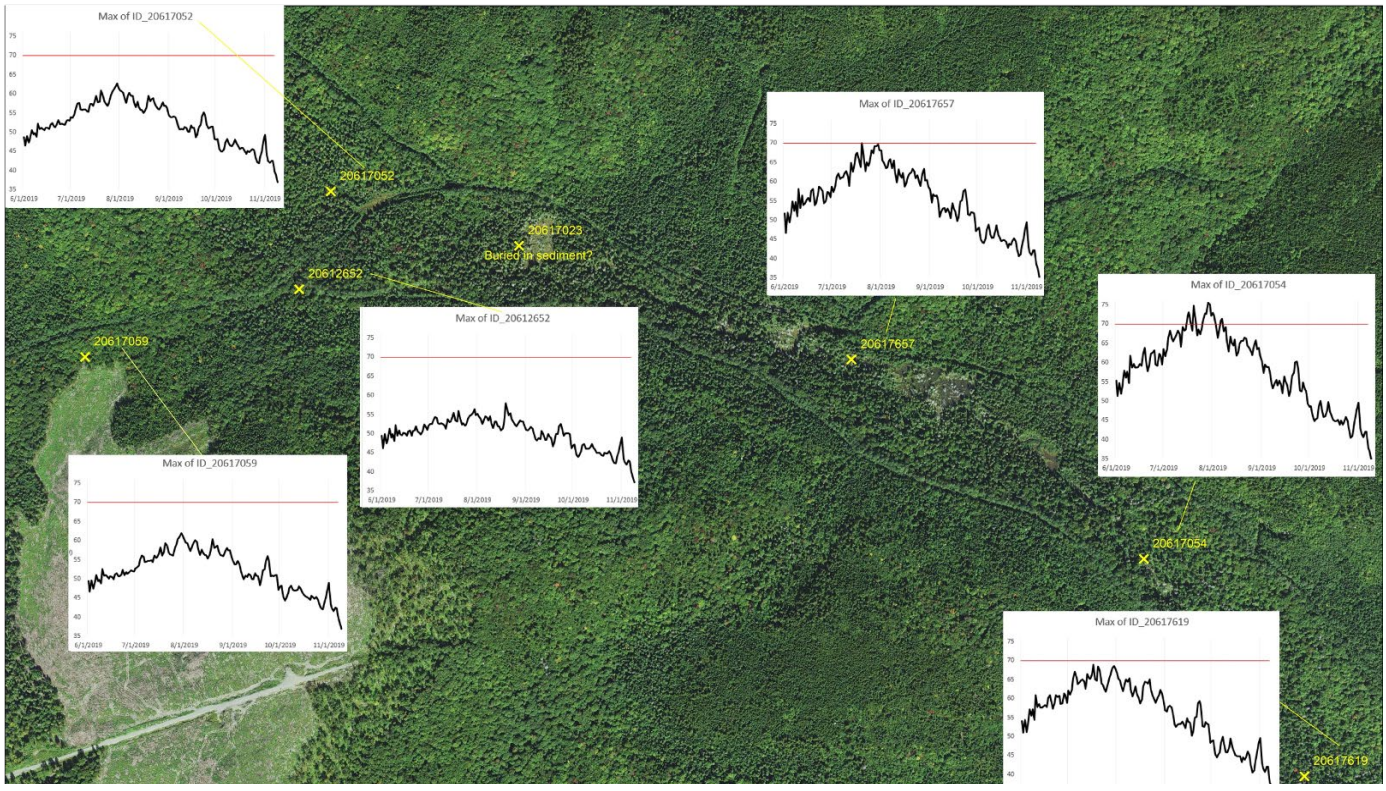
Dr. Sean Smith and students conducting stream measurements at Smith Brook, T14 R9 WELS. Photo N. Thompson, UMFK.

winter. A team of students led by Dr. Sean Smith of UMaine has conducted stream mapping exercises including physical measurements, pebble size counts, and stream mapping, providing baseline information for change detection and data for hydrological modeling.

UMaine students conducting stream measurements at Smith Brook, T14 R9 WELS. Photo N. Thompson, UMFK

Key Findings

Three years of temperature data collection have been completed, though final retrieval of 50% of the sensors has been delayed until the 2022 field season. The sample size in 2020/2021 is twice what was originally planned, growing from 85 to 180 as I replaced temperature loggers in Smith Brook with higher capacity models and redeployed the original set to the landscape wide study. Preliminary analyses suggest that stream gradient is strongly correlated to temperature, with higher-gradient (steeper) streams tending to be cooler. This result is based on the 10m resolution elevation model; further analysis using metrics from LiDAR are ongoing and will be completed when the last sensors are retrieved in the 2022 season.



2019 maximum daily temperatures (black lines) at six sites on the southernmost tributary to Smith Brook from June 1 through November 1. Stream flows from left to right across the map, with beaver constructions starting just below sensor 20617023.These sensors have since been replaced with models that collect year-round, and additional sensors have been placed in the area.

Future Plans

Collection and readout of the last temperature loggers in the landscape wide study is planned for Summer/Fall 2022. This will support analysis in Fall/Winter 2022 and subsequent final reporting and publication. Smith Brook is further delayed by one year as road construction was slowed by wet conditions in Spring 2022. The additional time will be utilized collecting additional baseline measurements and visual products, including 360 degree video walkthroughs of selected areas.

Products Delivered

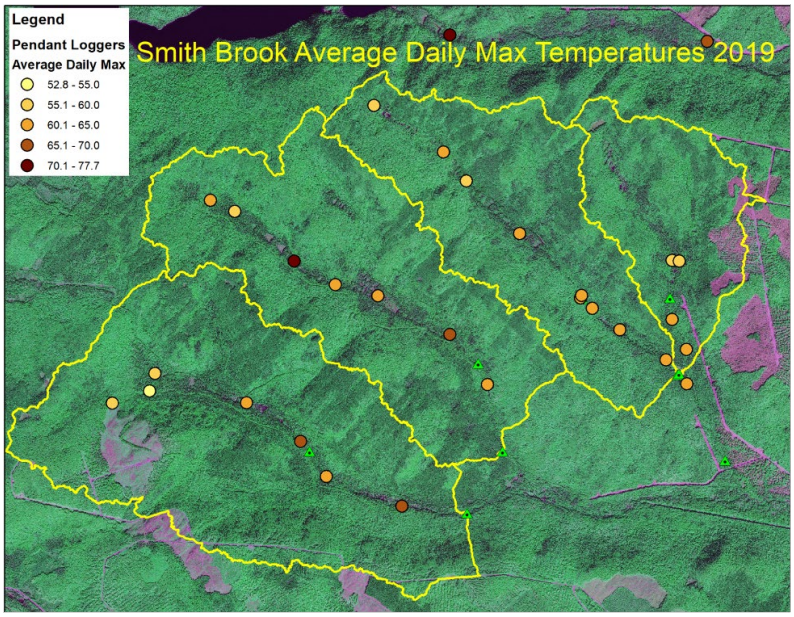
WRRI Stakeholders Meeting July 2022, discussing Smith Brook study and upcoming fieldwork. Attended by JD Irving Woodlands, LandVest LLC, Maine DEP, UMaine, and UMFK.

Partners / Stakeholders / Collaborators

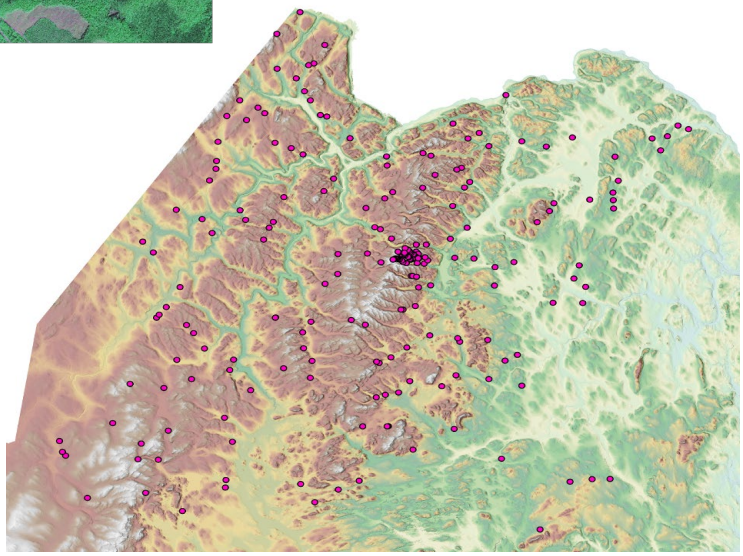
JD Irving Woodlands

Geographic Location of Project

Aroostook and northern Penobscot, Piscataquis, and Somerset counties - see map below.



Left: Smith Brook study area with 2019 temperature data displayed by average daily maximum temperatures in July and August. Green triangles mark the locations of pressure sensors used to record flow as well as temperature. This network has been replaced with year-round temperature loggers at a higher density than this initial layout. From bottom left to top right, operations are planned for 2023 (lower % removal), 2028, 2023 (higher % removal), and 2021 (higher).



Right: Layout of temperature loggers in all aspects of the project as of 2020/21, including the landscape-wide network and the Smith Brook network. Background displays 10m resolution elevation and hillshade.

Measurements, Models, and Maps: Toward a Reliable Cost-Effective Workflow for Large-Area Forest Inventory From Airborne LiDAR Data

Progress Report

Daniel Hayes, School of Forest Resources, University of Maine Orono
David Sandilands, Wheatland Geospatial Laboratory, University of Maine Orono
Anthony Guay, Wheatland Geospatial Laboratory, University of Maine Orono
Aaron Weiskittel, Center for Research on Sustainable Forests, University of Maine Orono

Abstract

Forests provide numerous benefits to society, and their sustainable management requires high-quality, accurate, and up-to-date information on their growing stock and condition. Geospatial analysis and related mapping technologies are increasingly in demand by forestry professionals and land managers to support inventory and monitoring of Maine's forest resources. In just the past few years, the rate of collection of remotely-sensed information on forest attributes over large areas has increased substantially. In particular, Airborne Laser Scanning (ALS) data measure ground elevation and tree canopy heights, characterize tree crowns, and provide a wealth of other detailed, 3-D information on forest structural characteristics. Maine's forests have now been covered with freely-available ALS data from the USGS, along with several updated and repeated sample areas acquired with high-resolution, research-grade data from NASA campaigns.

These datasets offer the opportunity to develop "Enhanced Forest Inventories" (EFIs) more accurately, efficiently, and with greater information content at lower cost relative to traditional methods. However, important questions remain with respect to developing EFIs including the impacts that sampling design and ground calibration plot types – along with the quality and characteristics of the ALS data – will have on model performance when estimating different forest attributes using an area-based approach. In this project, we set out to answer these questions as they pertain to using ALS and other remote sensing data for mapping key forest inventory variables across the mixed-species and structurally complex forests in Maine. We are conducting this research with a range of assessments from quantitative, statistical model comparisons to qualitative evaluations of product value and utility from the user community.

Rissa Currie, SFR 2023 & Wheatland Geospatial Lab Intern, collects EFI data in the Penobscot Experimental Forest.

Project Objectives

- To develop LiDAR metrics and models for accurately and consistently mapping EFI attributes over large managed forest areas in Maine.
- To evaluate the various plot layout and measurement requirements for calibrating ALS-based EFI models for large-area, mixed-species and structurally-complex forests.
- To produce, disseminate, and train stakeholders in the use of high quality EFI maps and analytics deliverables designed to inform the management of large forest areas.

Approach

In collaboration with forest industry stakeholders, the Wheatland Lab has designed a series of investigations into the use of LiDAR remote sensing to improve forestry inventory programs over large parcels of managed forestland. We are evaluating ground-based inventory plot designs together with existing, publicly-available ALS data sets processed in a high performance computing environment for generating geospatial data products useful in managing forests. In a series of demonstrative "case studies", we are working at several different private, public, and university research forest properties that represent a range of conditions in terms of the available ALS and accompanying field calibration plot data. We are using these case studies to evaluate the impact of calibration plot type, size, layout, and location accuracy on the estimation of forest inventory attributes using machine-learning models that relate the field data to wall-to-wall ALS across the different study areas. A key aspect of this project is working closely with stakeholders to "co-produce" the type of information that they need in a format that is most useful for their workflows. As the main deliverable from this project, we will synthesize the results and lessons-learned from the various case studies into a "Best Practices Guide" for ALS-derived EFIs for managers and practitioners in Maine.

Key Findings

An end-to-end workflow for area-based modeling of ALS data has been developed to create gridded maps of predicted EFI variables. A newly-implemented method uses the variability in the ALS data (calculated via principal components analysis, or PCA) to guide the number and placement of ground-based calibration plots. The lidR package in Program R is used to calculate the LiDAR metrics, the calibration data are prepared and organized in spreadsheets, and randomForest (Breiman 2001) is then used to perform the EFI variable prediction modeling. The results are quantitatively evaluated in terms of model explanatory power, average error, and bias in matching the predictions to the observations.

During the past year, we have applied this workflow to develop EFI products for new projects covering the Rangeley Lakes Heritage Trust and the Stephen Phillips Memorial Preserve Trust ownerships. The results of the models built for these can be compared to previous EFI projects with varying ALS and calibration plot data specifications. They demonstrate that precisely located fixed-radius calibration plots based on PCA-guided stratification yield improved model performance. Qualitative spot checks in the field were consistent with this determination.

We are also conducting a comprehensive EFI analysis for the University of Maine forest properties at the Penobscot Experimental Forest (PEF) and Demeritt Research Forest based on high-resolution ALS data (Figure1). A total of 140 calibration plots were selected and located on the map based on the PCA approach to identify unique forest structures across the variability in the LiDAR measurements. The total number of plots completed across the Demeritt and the PEF totals 238 including both PCA and CFI plots. These plots are being implemented through summer 2022 (Photo 1) and measured using different specifications to compare the impact on EFI model performance due to type (i.e. fixed- and variable-radius), shape (circular and square), and size.

Finally, we have conducted three workshops and presentations with a total of 257 participants (including CFRU members and other partners) to introduce the concepts, data, and methods of standard EFI workflows. These activities included hands-on demonstrations for building EFI maps and summary data products, with discussions around how to most effectively use them for analyses and use in the field.

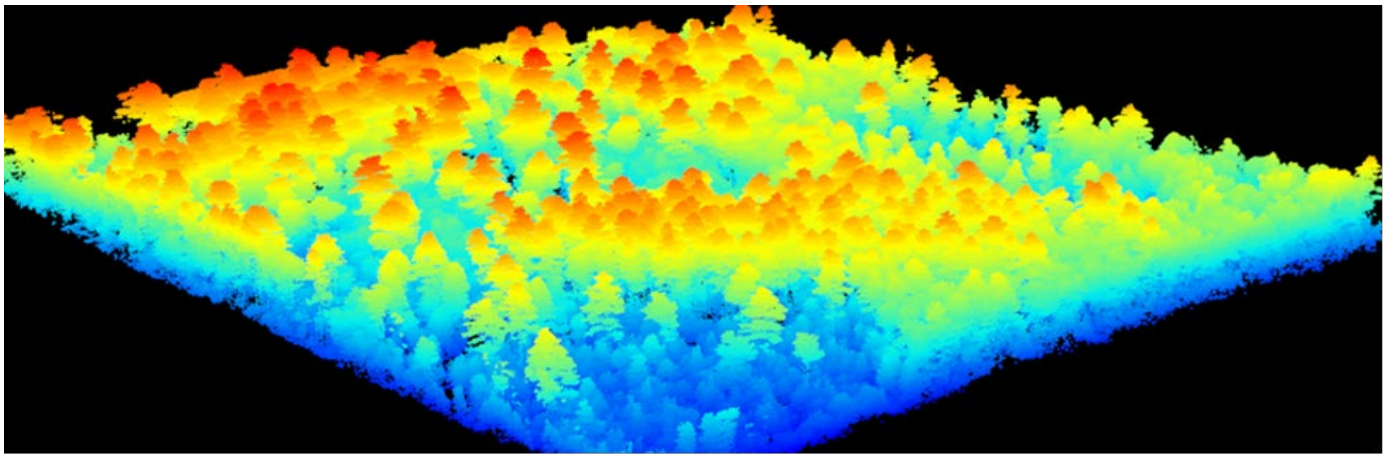


Figure 1. A visualization of a LiDAR data set acquired in summer 2021 with NASA's G-LiHT instrument in the Penobscot Experimental Forest, Bradley, Maine.

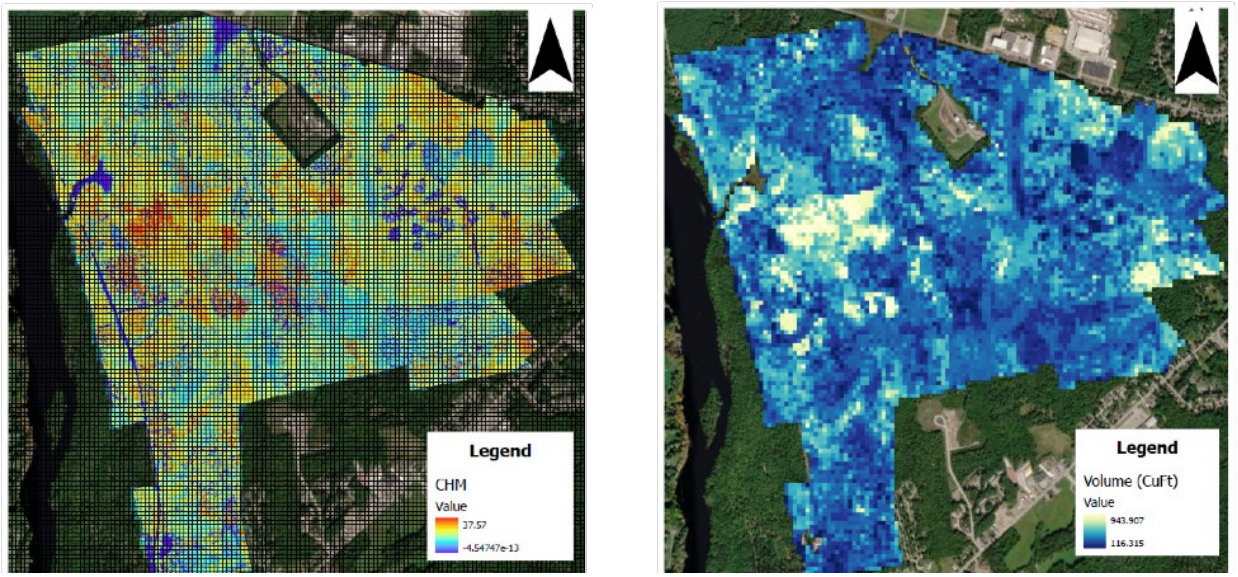


Figure 3. An example of output map products from LiDAR measurements and models showing canopy height (left) and standing volume (right) developed from NASA G-LiHT data collected for the Demeritt University Forest in Maine.

Future Plans

The ALS data sets have all been processed, the calibration plots data measured and data organized, and most of the EFI model runs have been completed (Figure 3). For the final project year, we will finish the remaining analysis of the model results and compare them across the various "experiments" that will answer our original questions related to how varying ALS and calibration plot data specifications impact the accuracy and usability of EFI estimates and map products. The compilation, synthesis, and analysis of all of the results across the different case studies is in progress. A set of recommendations are being developed based on these studies that will form the content of the "Best Practices Guide" for ALS-based EFI in Maine. We will continue to adhere to our timeline of project deliverables and associated communications plan, including holding technical workshops for CFRU members, disseminating our current findings in presentations to the stakeholder and science communities, and submitting the final report to the CFRU members on this project's key findings and accomplishments.

Dave Sandilands, WGL, and John Ackley, Weyerhaeuser, using UAV for orthoimagery at a MASN site

Partners / Stakeholders / Collaborators

Bruce Cook, NASA Goddard Spaceflight Center
Keith Kanoti, University Forests
Ian Prior, Seven Islands Land Company
Baskahegan Company
Rangeley Lakes Heritage Trust
Stephen Phillips Memorial Preserve Trust

Acknowledgments

We thank the CFRU members for their support of this project through a financial contribution, data sharing and general interest in this project's research and objectives. Special thanks goes to Seven Islands Land Company and the Maine Timberlands Charitable Trust for their active participation and strong support. It is very much appreciated and is critical to the WGL's mission of supporting geospatial education, research, and innovation needs of students, forest industry, and natural resource partners in Maine.

Geographic Location of Project

Maine, USA.

Spruce Budworm L2 Monitoring Program in Maine

Progress Report

Angela Mech, Assistant Professor of Forest Entomology, University of Maine Orono
Neil Thompson, Professor of Applied Forest Management, University of Maine Fort Kent

Abstract

In 2008, spruce budworm (SBW) initiated its current outbreak. With the previous outbreak having caused extensive ecological and economic losses, the ability to identify areas where SBW populations are growing exponentially had become of the utmost importance. The goal of this project was to establish a SBW processing lab in the state to allow land managers in Maine to make time-sensitive decisions about SBW control. This project was initiated mid-July 2021 with the hiring of the spruce budworm processing lab manager, James Stewart. Since then, James has helped clean up the space that would become the processing lab, ordered all of the necessary supplies, and set up the lab according to all safety protocols. We also worked with the Department of Industrial Cooperation at the University of Maine and set up the SBW storefront for processing jobs outside of those associated with the monitoring program, and on October 6th, 2021, the lab officially opened. All landowners/managers were supplied with collection bags for the 307 monitoring sites in Maine. All processing was completed in April 2022. Overall, there has been an increase in the number of L2's in Maine since 2020, with most of the population increases observed in the northern part of the state. Three sites were found to have population levels above the 7 L2 threshold.

Photo 1. Spruce budworm larvae. N. Thompson

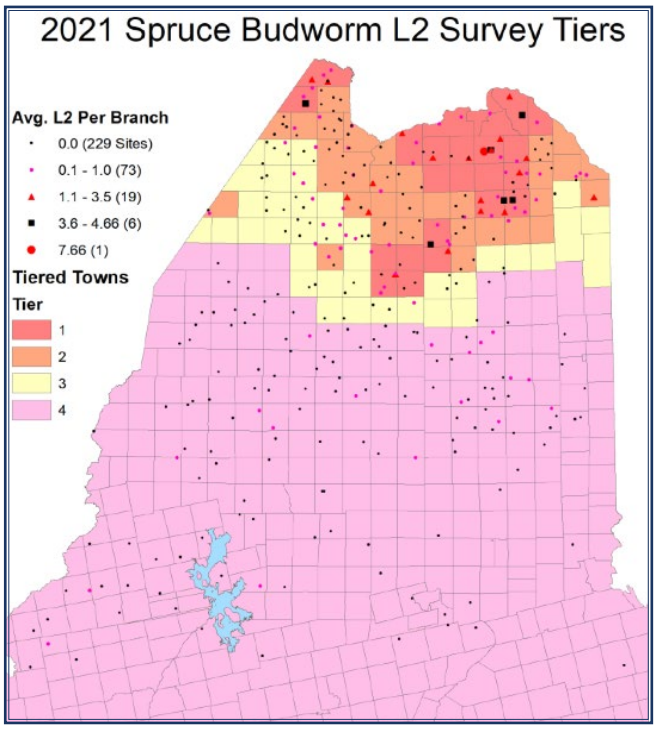


Figure 1. All 307 SBW monitoring sites broken down into priority tiers for the 2021 sampling season. Avg. L2 counts are from 2020 results. Map N. Thompson, UMFK

Project Objectives

- To establish a SBW processing lab at the University of Maine that would be responsible for determining the L2 counts for 307 monitoring sites across the state.
- To provide a fee-for-service option for landowners to have additional sites processed.
- To provide rapid results for areas that need to make management decisions quickly.

Approach

- Designated all 307 sites into 4 ranked tiers (Fig. 1) based on 2020 average L2 counts (avg. 3 branches per site) and proximity to hot spots.
- As branches arrive to the lab, they are sorted and processed based on tier.
- Landowners/managers are emailed results weekly if any of their sites have been processed.
- Any contract sites are processed as Tier 1's.

Key Findings

- A total of 292 sites (876 branches) were processed for the 2021 SBW monitoring season
- Monitoring results showed that the single 2020 hotspot site (7.7 L2's) was successfully decreased by management to 0.67 L2's in 2021.
- None of the 292 *monitoring* sites had > 7 L2's; the highest site average was 6.33 L2's.
- There has been a 30% increase in the overall average number of L2's per site compared to 2020 values. This indicates an overall growing trend in SBW populations, with most of the growth concentrated in the northern part of the state (Fig. 2).
- Overall, 28 sites had an average increase of 1 or more L2's compared to 2020 values, while 12 sites saw a decrease of an average of 1 or more L2's (Fig. 2).
- Processing was purchased for an additional 69 sites (207 branches). Three hotspots were found in Maine because of this additional sampling (Fig. 3).
- The highest average L2 count was 23.67

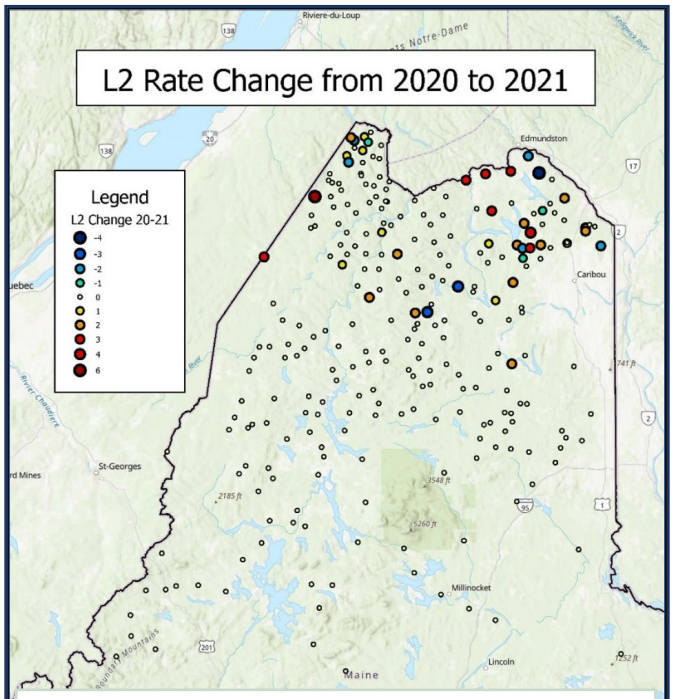


Fig 2. Change in the number of L2's found in 2021 compared to 2020. Changes were those that differed by an average of at least one L2.

Future Plans

- Conduct 2022 season SBW branch processing for 350 monitoring sites
- Provide fee-for-service option for additional site processing
- Include balsam woolly adelgid (Adelges tsugae) presence/absence in notifications to landowners/ managers.
- Leverage CFRU funds for additional financial support for the SBW lab
- Apply for funding to bring on a graduate student to study the trends of the current SBW outbreak

Partners / Stakeholders / Collaborators

Frank Cuff, Weyerhaeuser
Ked Coffin, J.D. Irving
Jim O'Malley, LandVest
Eugene Mahar, LandVest
Ian Prior, Seven Islands Land Co.
Allison Kanoti, Maine Forest Service
Mike Parisio, Maine Forest Service
Joe Bither, Maine Forest Service
Erin Simons-Legaard, University of Maine
Kasey Legaard, University of Maine
David Evanoff, University of Maine

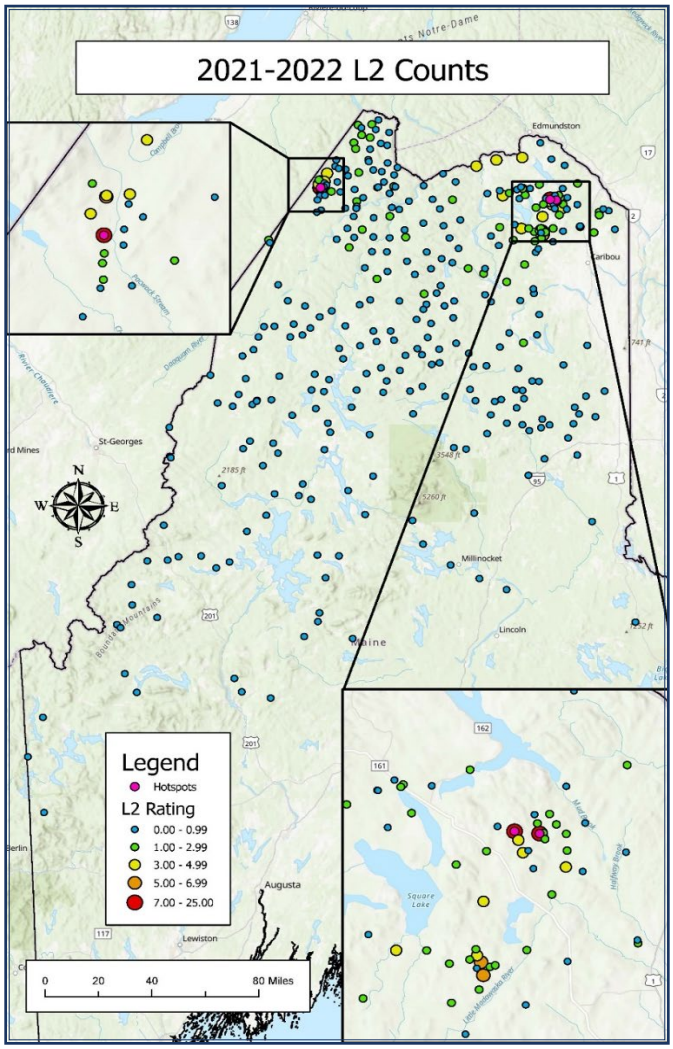


Fig. 3. Results of 2021 SBW L2 processing. Map includes 292 monitoring sites and 69 additional purchased sites. Insets show detected 2021 hotspots in Maine. Maps created by James Stewart.

Interdisciplinary spatial modeling of terrain, wetness soils, and productivity: new tools for forest management

Final Report

Dr. Colby Brungard, Environmental Soil Consulting, Las Cruces, NM, USA
Dr. Chris Hennigar, FORUS Research, Fredericton, Canada

Abstract

Digital soil mapping (DSM) was used to predict soil depths to bedrock, densic horizon, and redox features for the entire state of Maine at 5m spatial resolution. Many parametric and non-parametric models were compared, and quantile random forests produced the best models and provides users with the median, maximum, and minimum predicted depths of soil properties. Depths to bedrock, densic, and redoximorphic features predictions had an MAE of ±20cm, ±5cm, and ±12.5cm, respectively. Forest productivity was related to DSM predictions using LiDAR-derived stand height and 120,000 acres of harvest history data provided by CFRU members. Though 69% of stand height is explained by age and regeneration cover type, DSM and the Biomass Growth Index (BGI) explain an additional 3% and 5% of the variability of stand height, respectively, compared to the height: age equation alone. DSM explained 15% of the variability of forest regeneration type. DSM improvements to BGI were small.

Project Objectives

- Employ DSM techniques to generate spatial predictions for a suite of soil properties relevant to forest productivity by combining LiDAR-derived covariate layers with thousands of existing soil observations throughout the state of Maine.
- Relate variation in site productivity, measured by LiDAR stand height over age or USDA FIA plot growth rate, as a partial function of DSM variables, and if a relationship exists, then explore incorporation of DSM into existing Biomass Growth index (BGI) models or alternate mappable site productivity indicators.
- Produce spatial predictions of harvest operability, general harvest season, and/or soil rutting hazard by combining DSM soil properties with other relevant spatial layers in support of forest management. See future work section.

Approach

Digital Soil Maps

- Seven parametric and non-parametric models were generated to predict depths to bedrock, densic soil horizon (a root restricting layer), and redoximorphic features (a proxy for seasonally-high water table) using 5,660 georeferenced soil descriptions and over 140 LiDAR-derived raster covariates. Two step modeling was employed for all DSM models, with step one modeling presence/absence of the soil feature, and step two modeling the shallowest depth at which the feature occurs below the soil surface. Recursive feature elimination was used to minimize the number of covariates and produce the simplest models while maintaining model performance. Model performance was assessed using cross-validation (statewide) and a probabilistic validation sample (pilot areas).
- Spatial predictions of depth to bedrock, densic horizon, and redox features were generated statewide at 5m resolution.

Improving BGI with DSM

- FIA plot residual error from the most recent BGI models developed for Maine (Rahimzadeh-Bajgiran et al. 2020) was related against DSM variables with Random Forests to identify whether DSM variables could likely improve the BGI model. For DSM variables, null raster values (no soil growth restriction) were replaced with a value of 100 cm before intersecting with FIA plots.

Relating DSM and BGI to LiDAR height growth rate

- LiDAR point-cloud LAS files covering the northern and central study areas were downloaded from NOAA, reprojected from geographic to projected coordinate system (EPSG: 6348) with LASTools, and finally subdivided into 20m grid cells. Classified vegetation return heights were subtracted from classified ground return average heights in each 20m grid cell to yield normalized vegetation heights. Vegetation height for each 20m grid cell was calculated as the 95th percentile of vegetation returns for the two study areas (Fig. 1).

- Originally, we explored use of LANDSAT harvest history predictions from 1985-2010 (Goward et. al. 2015) to factor out age influence on vegetation height, to detect a DSM effect; however, extensive variability in harvest treatments in Maine, most with only partial removal of the canopy and multiple harvest entries, combined with the low disturbance resolution of this LANDSAT layer, made it very difficult to identify a reliable measure of forest age. To gain more spatially accurate harvest history for the northern study area, CFRU members (JD Irving, Prentiss & Carlisle, LandVest, and Seven Islands) provided about 120k acres of polygon harvest history between 1985 and present, including: type of harvest (overstory removal, clearcut), year of harvest, type of regeneration (hardwood, mixedwoods, softwood) and silviculture history. No detailed harvest history was available for the central study area.
- Average height was computed for each stand, and stands were limited to clearcuts ≥ 1 hectare, ≥ 5 years-old (LiDAR capture year minus harvest year), and with an average height in meters < stand age to remove extreme outliers in the data (highly unlikely to have average 10m vegetation at age 10). A Chapman-Richards mixed-effects model was used to fit height as a function of age with random-effects of regeneration cover-type on the age term. Mean stand DSM variables (Lithic, Redox, Densic, Root Depth) and BGI were used in various model iterations within the asymptote term to try and explain height growth rate variation and gauge relative contribution of each. For DSM variables, null raster values (no soil growth restriction) were replaced with a value of 100 cm before stand averaging.

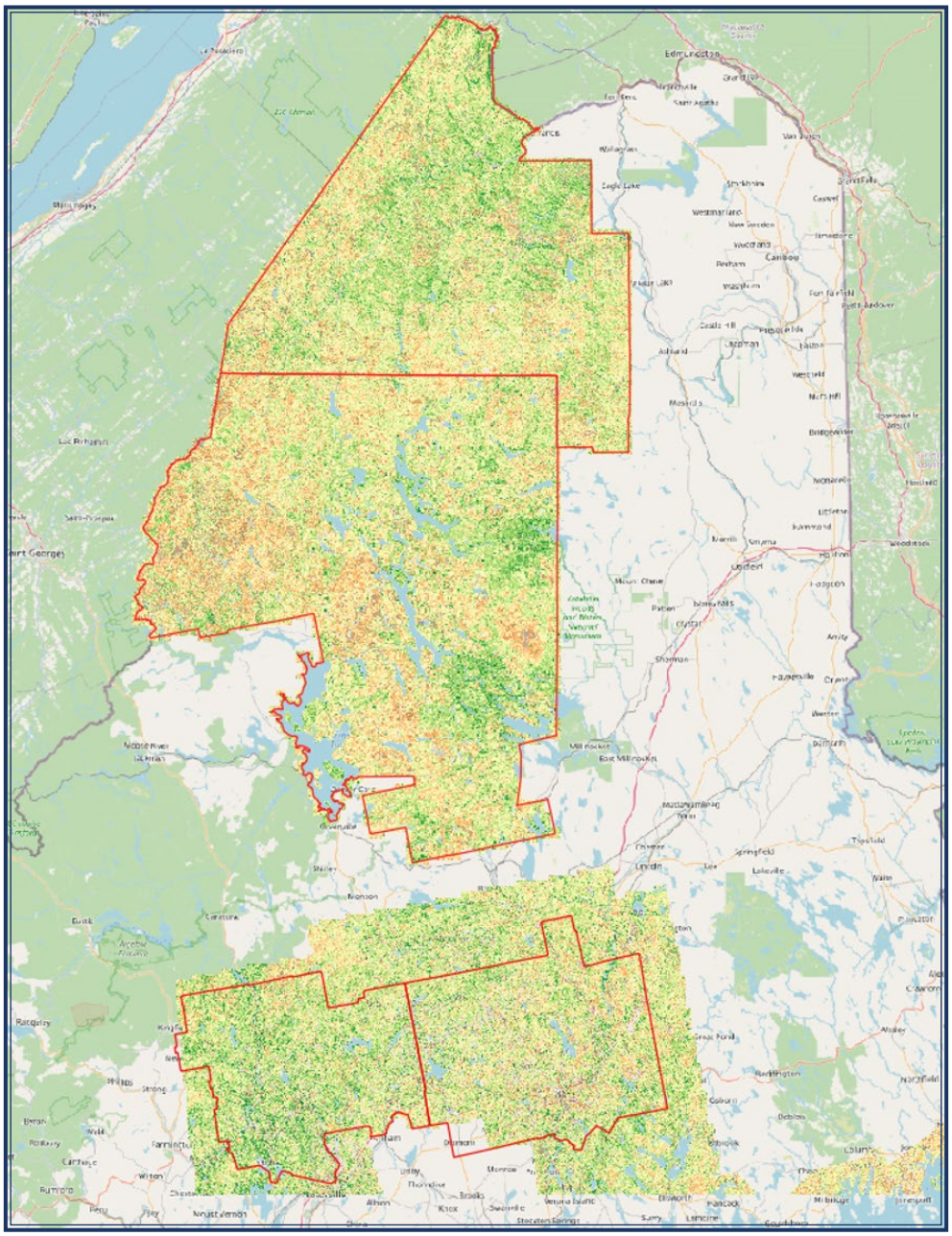


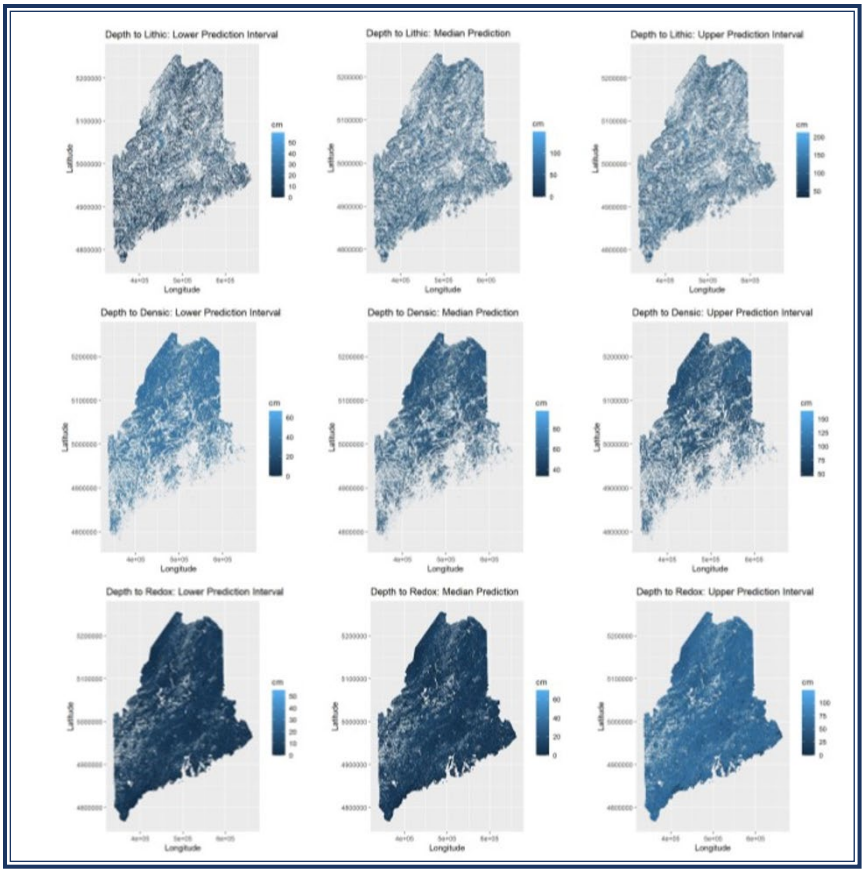
Figure 1. LiDAR 95th percentile vegetation height (color scale: green >= 20m = orange < 5m) on a 20m grid for the northern and central Maine study areas (red boundaries).

Key Findings

- Though several statistical models performed well and an ensemble model was considered (a combination of several models), the quantile random forest algorithm consistently outperformed other models and was used to generate all spatial predictions statewide at 5m pixels. Depths were predicted for the 0.05, 0.5, and 0.95 quantiles so that forest managers can know the median predicted depth as well as a range of likely high and low depths to expect for each soil property at any given location (Fig. 2). Mean Absolute Error (MAE) and Root-Mean-Squared-Error (RMSE) of the quantile random forest models are summarized in Table 1.

Soil Property Modeled	MAE (cm)	RMSE (cm)
Depth to Bedrock	±20	±27.5
Depth to Densic	±5	±7.5
Depth to Redox	±12.5	±17.5

Table 1. Mean Absolute Error (MAE) and Root-Mean-Squared-Error (RMSE) of the quantile random forest models.



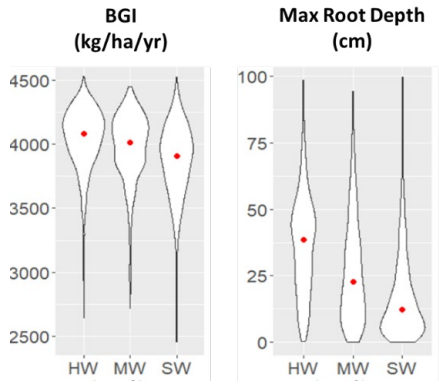


Figure 2 (left). Spatial predictions of depth to bedrock, densic horizon, and redox features (rows) for the 0.05, 0.5, and 0.95 quantiles at 5m resolution using quantile random forest models.

Figure 3 (above). Violin graphs showing stronger separation of regeneration cover type (HW – hardwood, MW – mixedwood, SW – softwood) with DSM max root depth than biomass growth index, and clear trends toward higher hardwood content on less restrictive sites, excluding plantations.

- Of the DSM layers included as variables in site productivity modeling, Maximum Root Depth (RD) consistently performed the best, with depth to redox contributing most of the explanatory power to the RD variable. Maximum rooting depth was derived by stacking DSM predictions for depth to bedrock, depth to densic horizon, and depth to redox layers and assigning the value of the most root-limiting layer predicted to each pixel. This RD variable is a metric of available rooting volume for plants.

Improving BGI with DSM

- DSM outperformed existing soil restriction and water depth variables used in the original BGI by only 3%, as expected, prompting a shift in effort toward development of a more precise measure of site productivity derived from LiDAR height and stand age.

Relating DSM and BGI to LiDAR height growth rate

- RD explained about 15% of the variation in regeneration type (three times more correlated than BGI), with softwood regeneration increasing with decreasing rooting volume and hardwood regeneration increasing with increasing rooting volume (Fig. 3), excluding plantations.
- Most of the variation in LiDAR-derived average stand height was explained by stand age and regeneration cover type (69%). Incorporating RD and BGI into the asymptote term of the height: age equation explained an additional 3% and 5% of residual height error, respectively, compared to using only age (Fig. 4). This increased to 6.7% by using both BGI and RD combined (eq. 1).

Equation 1.

$$\textbf{Height}_{95} = (a_0 + a_1 * BGI + a_2 * RD) * (1 - \exp(-b * Age))^c$$

where $a_0 = 5.457178$, $a_1 = 0.001943$, $a_2 = 0.0117$, $b = 0.103076$, $c = 1.914426$. *All variables were highly significant.*

- A relative site index was calculated and used to map the combined effect of BGI and RD on height predictions for the entire state of Maine on a 20m grid by dividing the location asymptote by the maximum asymptote, as defined in equations 2a and 2b (Fig. 5). Values range from 0-1 for worst to best sites.

Equation 2a.

Relative site index = *location asymptote / max asymptote*

OR

Equation 2b.

$$\textbf{Relative site index} = \frac{a_0 + a_1 * BGI + a_2 * RD}{a_0 + a_1 * {}^{BGI}max{=}5800 + {}^{a2 * RD}max{=}100}$$

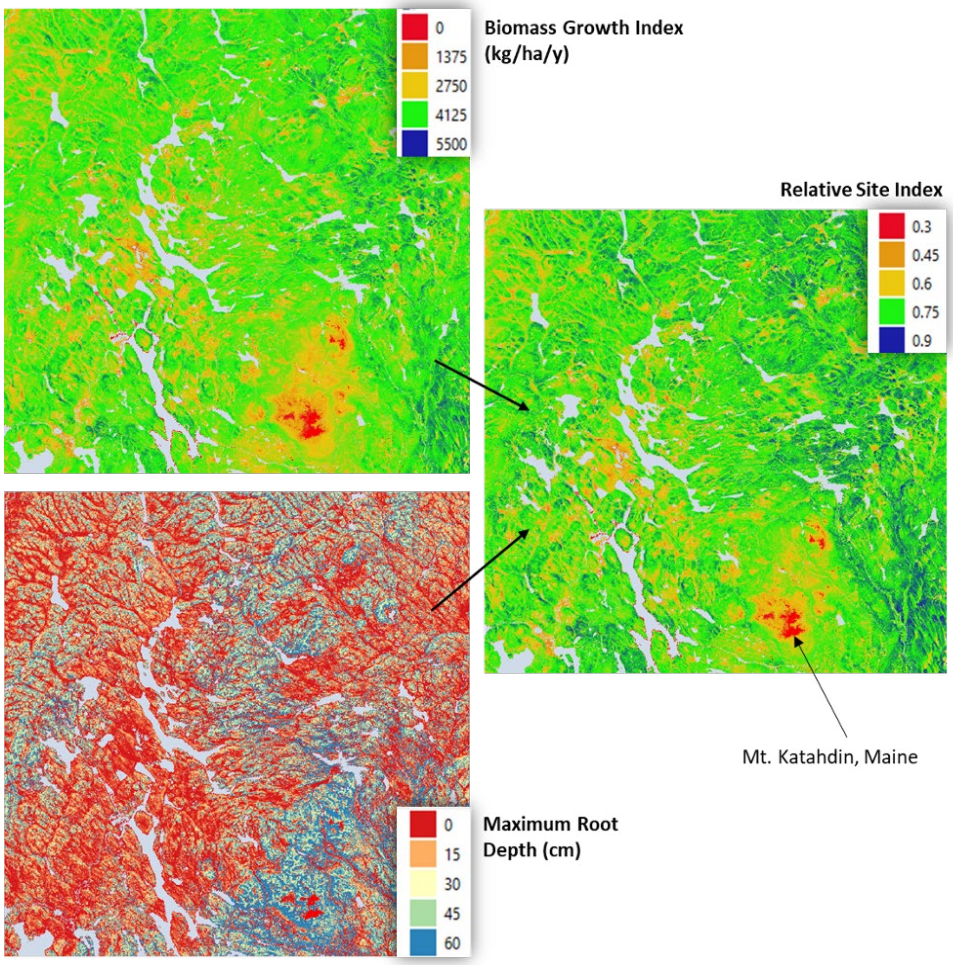


Figure 5. Integration of biomass growth index (Rahimzadeh-Bajgiran et al. 2020) and maximum root depth using equation 2b.

Future Plans

- At the discretion of the CRSF Director, the PI on this project will work one more year to complete the third project objective since one of the original Co-PIs accepted a new job shortly after this project began. In the coming year Dr. Brungard will work with NRCS partners to create custom forest management layers for harvest operability, general harvest season, and soil rutting hazard.
- While not the focus of this project, predicting regeneration type with DSM was a notable outcome and potential future application of this work.
- Adding other DSM variables (nutrients, texture, coarse fragments) would be a good next step to improve the BGI. Other useful next steps would be updating Dr. Paul Arp's Depth to Water Table map with LiDAR and adding refined climate variables from ClimateNA with LiDAR-DEM temperature adjustments to replace coarse 800m grid predictions used in the BGI models would help.
- Accurate measures of forest productivity have proven challenging to acquire given the range of species responses to site and local variation in forest management practices and natural disturbances. Establishing extensive site index sampling points across Maine is hampered by cost and reliance on many independent landowners. Time-series LiDAR or radar acquisitions that directly measure forest growth may be the most efficient and practical way to gain clearer growth response to site factors through the sheer volume of observations.

Products Delivered

All final products can be accessed and downloaded by CFRU members at cfrumembers.org

- Spatial predictions of depth to bedrock, densic horizon, and redox at 0.05, 0.5, and 0.95 quantiles (see Fig. 2) and uncertainty layers, can be downloaded here: DSM deliverables. Cell size is 5m and projection is EPSG:26919 NAD83 / UTM zone 19N.
- All R scripts are available for CFRU members.
- LiDAR derived scaled and compressed environmental covariate layers will be provided to the NRCS soil survey and are available upon request. Because these statewide variables are ~ 500 GB in total size it is difficult to share them on-line at this time.
- Relative BGI-DSM site index map of Maine. For efficient distribution, raster relative values were multiplied by 100, converted to byte, and compressed. Cell size is 20m and projection is EPSG:26919 NAD83 / UTM zone 19N. In use, this layer should be overlayed with known non-productive or non-forest features, as site predictions are only applicable to productive forest land.

Acknowledgements

- CFRU Members and Funding Support
- Staff at JD Irving, Prentiss & Carlisle, LandVest, and Seven Islands
- NOAA technical support for LIDAR files
- Sean Lamb, FORUS Research
- Aaron Weiskittel, University of Maine
- NRCS staff (particularly Alaina Kresovic, Joshua Dera, and Jasmine Gregory) for assisting with soils data entry and field data collection of the validation dataset.

Partners / Stakeholders / Collaborators

- Jamin Johanson & Nicholas Butler - USDA-NRCS

Geographic Location of Project

- Central Maine Pilot Area – Penobscot and Southern Somerset Counties - *soil survey areas ME602 & ME612*
- Northern Maine Area – *soil survey areas ME621 & ME622*
- Entire state of Maine

Professional and Student Involvement

	Names	Degree Sought	Time Allocated (CFRU Funds) hrs/week or FTE
Professionals	Nicholas Butler (NRCS) Alania Kresovic (NRCS) Joshua Dera (NRCS)		160 hrs 160 hrs 160hrs
Graduate Students	Jamin Johanson	Ph.D.	120 hrs
Summer Students	Jasmine Gregory	B.S.	60 hrs

Above: Digital Soil Mapping team and NRCS employees in the fall of 2021for a CFRU field tour.
Left to right below: Presenters in the field: Jamin Johanson NRCS, Colby Brungard Environmental Soil Consulting.

High Resolution Land Cover and Forest Type Data for the State of Maine

Progress Report

Kasey Legaard, Research Assistant Professor, School of Forest Resources & CRSF
Anthony Guay, Wheatland Geospatial Laboratory, University of Maine Orono
Claire Kiedrowski, Executive Director, Maine GeoLibrary

Abstract

The Maine High Resolution Land Cover project will produce in partnership a multi-resolution set of land cover products for the state, providing an appropriate level of detail for a wide variety of applications. Data development will include a 1-meter land cover product, consistent with NOAA's Coastal Change Analysis Program (C-CAP), and a 10-meter land cover product including C-CAP classes plus detailed forest type categories developed by the University of Maine Intelligent GeoSolutions group, housed under the Center for Research on Sustainable Forests. Both layers will be readily updatable, with planned updates tied to the 4- to 6-year NOAA C-CAP production cycle to reduce future costs. Regularly updated 1-meter and 10-meter layers will provide statewide land cover and forest type data with unprecedented spatial, temporal, and thematic detail. This next-generation, multi-resolution data will support a broad range of forest sector use cases and applied research topics of importance to the CFRU.

Project Objectives

- Develop a forest typing scheme (approx. 15 forest types) suitable for remote sensing application throughout the state of Maine given available resources and forest stakeholder priorities;
- Develop methods to harmonize 10-meter satellite-derived forest type predictions with new 1-meter land cover data obtained from digital aerial photography and LiDAR;
- Produce and distribute a statewide 1-meter land cover product (17 categories, including natural vegetation, wetlands, and impervious surfaces);
- Produce and distribute a statewide 10-meter land cover and forest type product (the current plan includes 15 forest type categories plus 16 non-forest and disturbed forest categories);
- Develop a data maintenance plan including a 4- to 6-year update cycle coordinated with federal, state, and university programs to reduce future cost.

Approach

- Production of land cover and forest type data will be accomplished through a partnership between the NOAA Office for Coastal Management and UMaine IGS. Production and delivery of the 1-meter land cover data will be coordinated by NOAA. Production and delivery of the 10-meter land cover and forest type map will be coordinated between the NOAA Office for Coastal Management and UMaine IGS, with NOAA responsible for aggregating 1-meter land cover categories to a 10-meter grid and IGS responsible for modeling and mapping the condition of forest pixels at 10-meter resolution.
- Methods used to produce the 1-meter data will be consistent with those used to produce the NOAA C-CAP product line [1], and will include

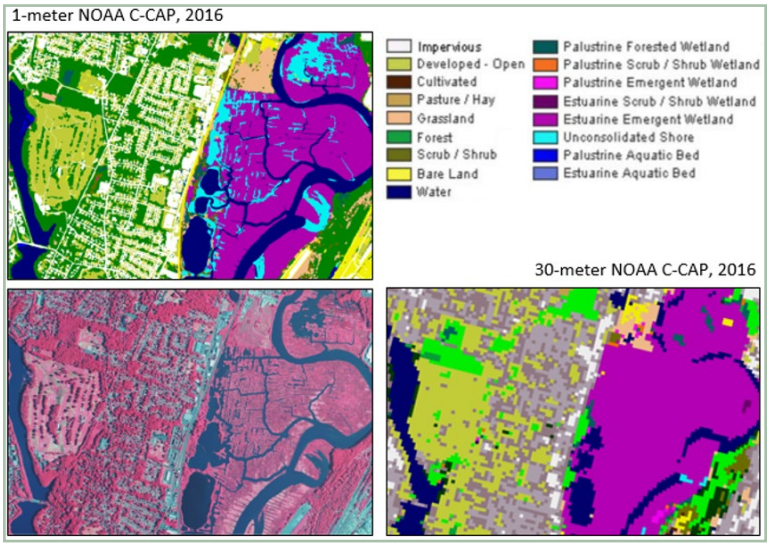


Figure 1: Sample landscape demonstrating the spatial detail resolved by the 1-meter NOAA C-CAP High Resolution Land Cover product line, contrasted with the 30-meter NOAA C-CAP Regional Land Cover data.

a combination of machine learning applied to digital aerial photography and LiDAR, geographic object based image analysis, expert-based rulesets, and manual editing (Figure 1).

- Forest classification will rely on machine learning and geographic object based analysis methods developed by UMaine forest scientists [2-3] and implemented with software developed in partnership with the University of Maine Advanced Computing Group.
- Input data will include multi-temporal Sentinel-2 satellite imagery and digital terrain data. Primary training and validation data will be contributed by the USDA Forest Service, Forest Inventory and Analysis Program under an existing collaborative agreement with UMaine (Figure 2).
- Forest type predictions will be based on the identification of dominant or co-dominant tree species or species groups (e.g., Populus spp.), obtained from 10-meter resolution predictions of species relative abundance (e.g., percent of total live aboveground biomass). Our proposed forest type scheme includes 12 upland classes (4 hardwood, 4 softwood, and 4 mixedwood classes) and 3 lowland or forested wetland classes (Table 1).

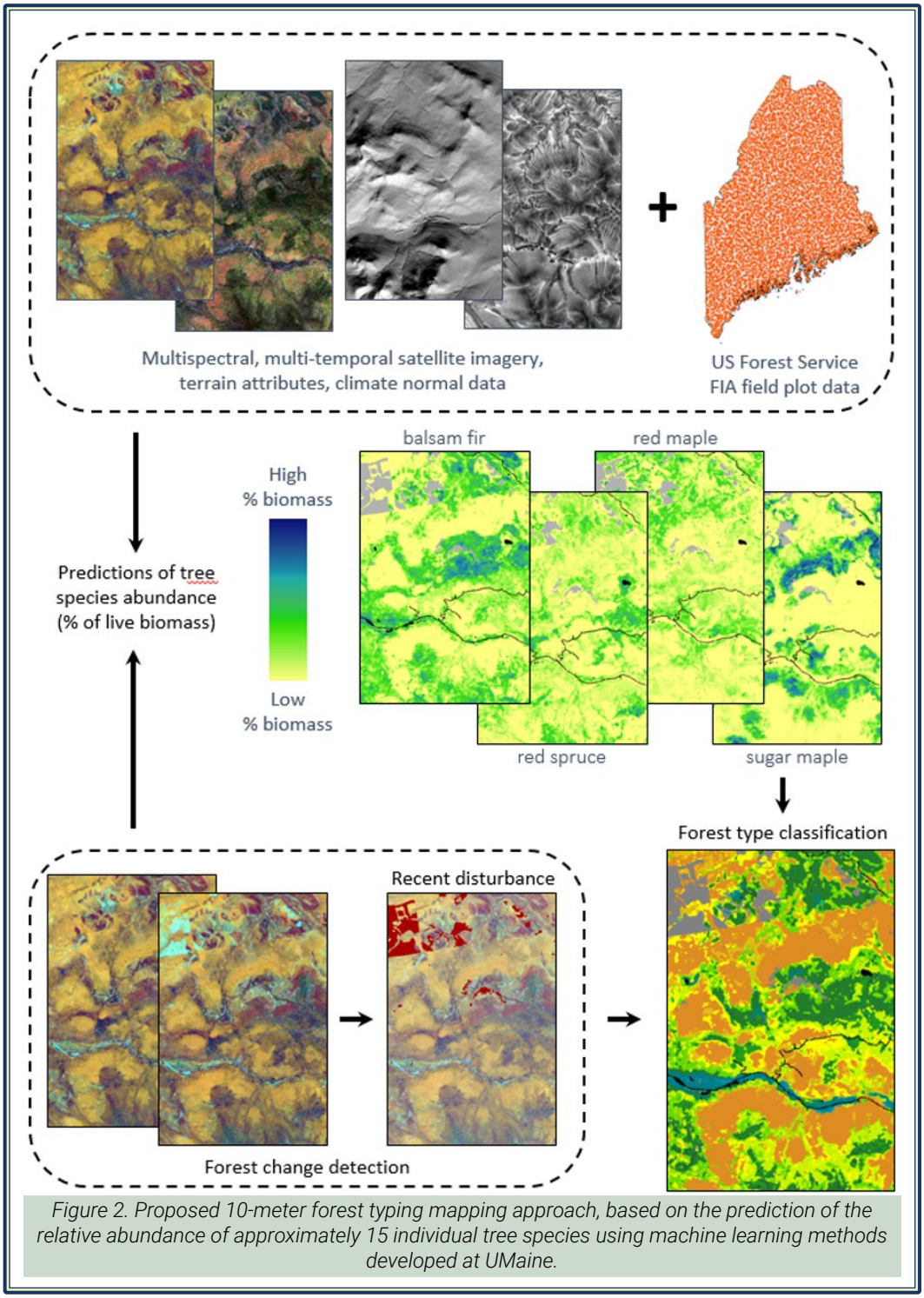


Figure 2. Proposed 10-meter forest typing mapping approach, based on the prediction of the relative abundance of approximately 15 individual tree species using machine learning methods developed at UMaine.

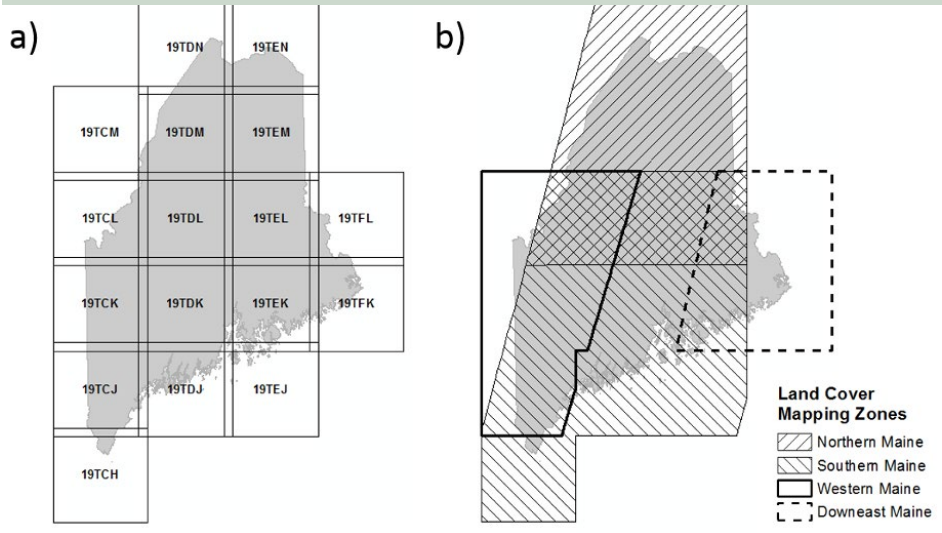
Table 1: Proposed forest type and forest disturbance classes for the Maine High Resolution Land Cover project, 10-meter land cover and forest type map.

Upland Forest Types (12 classes)		
Aspen Birch	Aspen-Birch mixedwood	Cedar-Black Spruce
Maple-Beech-Birch	Hemlock mixedwood	Hemlock
Oak	Fir-Spruce mixedwood	Fir-Spruce
Red Maple	Spruce-Pine mixedwood	Spruce-Pine
Lowland Forest Types (3 classes)		
Hardwood-dominant forested wetland	Mixedwood forested wetland	Softwood-dominant forested wetland
Recent forest disturbance (1 class)		

Key Findings/Accomplishments

- We constructed decision criteria associated with our proposed forest typing scheme, and summarized species associations within forest types by applying decision criteria to reference plot data. Decision criteria determine forest type assignments predominantly on the basis of the predicted relative abundance of indicator tree species (species whose dominance or codominance are considered indicative of forest type).
- We assembled and processed Sentinel-2 satellite imagery suitable for statewide forest mapping. Preliminary outcomes over trial areas (to be determined in consultation with the NOAA Office for Coastal Management) will inform the selection of a final set of image data and may lead to further refinement of data processing procedures.
- Sentinel-2 data include acquisitions obtained between late May and early November to leverage growing season phenology for species differentiation. Frequent and extensive cloud cover constrain the collection of suitable image data for large-area mapping applications, and we therefore use cloud-free or nearly cloud-free imagery acquired over a multi-year period (2017-2021).
- We have defined four overlapping mapping zones within which we will independently model and map tree species relative abundance as a basis for forest typing (Figure 3). Mapping zones were largely defined by Sentinel-2 orbital footprints and tile boundaries, patterns of cloud cover on individual acquisition dates, and the spatial distributions of reference observations. Seamless statewide mosaics of species abundance will be generated prior to the assignment of forest types.

Figure 3: (a) Sentinel-2 tiles intersecting the state of Maine. (b) Forest mapping zones defined by orbital paths, tile boundaries, tree species distributions, and cloud cover in individual Sentinel-2 acquisitions.



- We have processed 7-8 predominantly cloud-free image acquisitions for each of the four mapping zones, although alternative combinations of image data will be evaluated as the project progresses. Thus far, we have processed a total of 205 images for use as primary predictor data. Image processing steps include band resampling and stacking to 10 m resolution, conversion to top-of-atmosphere reflectance, local coregistration to a reference cloud-free leaf-on Sentinel-2 image, haze correction, cloud and shadow detection and masking, and topographic illumination correction.

Future Plans

July 2023 - June 2024

- Preliminary species model training and validation of predictions.
- Review and refinement of image processing procedures and outcomes.
- Preliminary map production and evaluation over trial areas selected in coordination with the NOAA Office for Coastal Management.
- Review and finalization of forest type decision criteria, machine learning models, and predictor data selection and processing.
- Development of methods, in collaboration with the NOAA Office of Coastal Management, to harmonize 10-meter satellite-derived forest type predictions with 1-meter land cover data obtained from digital aerial photography.
- Final production and distribution of statewide 1-meter and 10-meter land cover and forest type data products (including complete metadata conforming to ISO standards).
- Multiple presentations to local, state, regional, and federal stakeholders. Plans currently include presentations to the CFRU, the Maine GeoLibrary Board, the Maine GIS User Group, the 2022 Northeast Arc Users Group Conference, and the 2022 Forest Inventory and Analysis (FIA) Science Stakeholder Meeting.

Partners/Stakeholders/Collaborators

- Baxter State Park
- Maine Bureau of Parks and Lands
- Maine Department of Environmental Protection
- Maine Department of Transportation
- Maine Library of Geographic Information
- Maine Natural Areas Program
- NOAA Office for Coastal Management
- The Nature Conservancy
- University of Maine Advanced Computing Group
- USDA Forest Service, Northern Research Station FIA Program

Professional and Student Involvement

	Names	Degree Sought	Time Allocated (CFRU Funds) hrs/week or FTE
Professionals	Larry Whitsel Ken Bundy		1 month @ .5FTE NA

Geographic Location of Project

State of Maine (using plot data collected statewide; producing map data statewide)

Presentations, Workshops, & News Articles

- Forbes, A. (2021, October 6). New Spruce Budworm Testing Lab at UMaine critical to mitigating impact of destructive insect. University of Maine Press Release. https://bangordailynews.com/2021/10/06/homestead/the-destructive-spruce-budworm-is-back/
- Hagan, J. Presentation to the Maine Forest Products Council SFI-SIC Committee, December 1, 2021. (virtual)
- Hagan, J. Presentation at the Maine Woodland Owners Association Annual Meeting, January 12, 2022. (virtual)
- Hagan, J. Presentation to NCASI, April 20, 2022. (virtual)
- Hagan, J. The Great Ragmuff Clearcut. Forestry Source. February 2022, Vol. 27, No. 2. https://www.bluetoad.com/publication/?i=736243 (subscription required)
- Hayes, D. (2022, April 12). The Use of Lidar for Enhanced Forest Inventory [Presentation]. NERCOFE Meeting.
- Hayes, D. (2022, June 22). Lidar Enhanced Forest Inventory Demystified [Presentation]. Barbara Wheatland Geospatial Analysis Laboratory.
- Hayes, D. (2022, March 25). Lidar Enhanced Forest Inventory Demystified [Workshop]. NESAF Winter Meeting.
- Holloway, D. (2021, October 21). New UMaine lab dedicated to spruce budworm research. FOX 22 WFVX Bangor. https://www.foxbangor.com/news/item/new-umaine-lab-dedicated-to-spruce-budworm-research/
- Kenefic, L., R. Seymour, N. Rogers, C. Ziegra, K. Kanoti. 2022. A Working Session on the New Silvicultural Guide for Spruce-Fir. New England Society of American Foresters Annual Meeting, March 23, 2022, South Portland, ME. Oral presentation.
- Levy, J. Three decades of bird response to forest management in Northern Maine. 2022 New England Society of American Foresters Annual Meeting--Conservation Conversations, Avian Ecology and Forestry session. March 23, 2022, Portland, ME.
- Schipani, S. (2021, October 6). The destructive spruce budworm is back. Bangor Daily News. https://bangordailynews.com/2021/10/06/homestead/the-destructive-spruce-budworm-is-back/
- Thompson, N. (2022, July) WRRI Stakeholders (JD Irving Woodlands, LandVest LLC, Maine DEP, UMaine, and UMFK) Meeting. Smith Brook study and upcoming fieldwork [Discussion].