Proceedings of the 8th Eastern CANUSA Forest Science Conference

Understanding and Managing ECANUSA Forests in a Changing Environment

Davis Center, University of Vermont
September 30 – October 1, 2016

Cover Photo – "Mansfield Transitions" John Heselton

About the 2016 ECANUSA Conference

Understanding and Managing ECANUSA Forests in a Changing Environment

The *Eastern CANUSA Forest Science Conference* was developed to provide a regular venue for communications among forest managers, forest scientists, policy makers, students, natural resource professionals, and others interested in forest resource issues from both sides of the Canadian/US border.

Because of the northern forest's importance to the region, forest managers and researchers from the northeastern states and eastern Canadian provinces are working continuously to find solutions to a wide variety of natural resource problems. Great work is occurring on both sides of the border that are enhanced by regular information exchange about issues affecting the northern forest. This ECANUSA meeting serves as a forum to promote ongoing discussions and collaborations about the latest forest problems, methods, findings, and technologies.

This year we focus on the many stressors and agents of change converging on the region's forests. As in past years, the conference will include a full day of plenary and concurrent oral presentations, a poster session and a half day field tour. Friday evening will also include a reception, dinner banquet and a keynote speaker. Scientists and practitioners from a large spectrum of expertise will be presenting on research, monitoring, management and outreach activities to address the many challenges that our changing environment present to the sustainable management of the regions forest resource.

For more information on the 2016 UVM ECANUSA meeting visit:
https://www.uvm.edu/femc/ecanusa2016

For more information on the ECANUSA collaborative visit:
https://crsf.umaine.edu/outreach/ecanusa/

ECANUSA 2016 Planning Committee

Anthony D'Amato
University of Vermont

James Duncan
Vermont Monitoring Cooperative

Gary Hawley
University of Vermont

William Keeton
University of Vermont

Jennifer Pontius
USFS Northern Research Station
University of Vermont

Paul Schaberg
USFS Northern Research Station

ECANUSA 2016 Scientific Committee

Laura S. Kenefic (US Forest Service NRS)
Collin Beier (SUNY ESF)
Chris Woodall (US Forest Service NRS)
Dianne Burbank (US Forest Service GMNF)
Josh Halman (VT FPR)
Aaron Weiskittel (UME)
Dave Kittredge (UMA)
Mary Tyrrell (Yale)
Daniel Kneeshaw (UQUAM)
Phillipe Nolet (Institute des Sciences de la Forêt Tempérée)
Patricia Raymond (Government of Quebec)
Ted Howard (UNH)

A special thank you to our graduate and undergraduate student Conference Facilitators: Cathleen Balantic, David Gudex-Cross, Alexandra Kosiba, Nicole Rogers, and Tami Wuestenberg for their help in facilitating the plenary session question-and-answer process, and moderating the afternoon concurrent sessions.

Preferred Citation:

Abstract Author. 2017. Abstract Title. *In: Proceedings of the 8th Eastern CANUSA Forest Science Conference: Understanding and Managing ECANUSA Forests in a Changing Environment.* Pontius, J., Schaberg, P. and J. Duncan (Eds.) September 30-October 1, 2016. Burlington, VT. Forest Ecosystem Monitoring Cooperative. pp XX-XX.

Digital Object Identifier: doi:10.18125/D2MW2X

Available online at https://www.uvm.edu/femc/ecanusa2016#proceedings

TABLE OF CONTENTS

KEYNOTE
HOW SILVICULTURE CAN HELP FORESTS COPE WITH A CHANGING ENVIRONMENT: INSIGHTS FROM QUEBEC'S TEMPERATE MIXEDWOOD FOREST

Patricia Raymond [(1)]

[(1)]*Direction de la recherche forestière, Ministère des Forêts, de la Faune et des Parcs du Québec 2700 rue Einstein, Québec, Québec, Canada, G1P 3W8, patricia.raymond@mffp.gouv.qc.ca*

ABSTRACT

While land managers are facing the great challenge of managing forests over the next decades in a changing environment, one of the crucial question remains "What can we do now to manage forests and help them to face future conditions?" This presentation aims to provide insights about how silviculture can help forests cope with a changing environment, using examples drawn from Québec's temperate mixedwood forest.

KEY FINDINGS

- Diversity will decrease the risk of negative interactions with stressors.
- Resilience will help the most complex stands to cope with and recover from stressors.
- Transition options should help new stands evolve under changing conditions.
- A general strategy of adaptation should focus on integrating options that favor resilience in older stands, adaptation in intermediate stands and transition in younger stands.

One striking realization when we start thinking about this question from a land manager's perspective is the high level of uncertainty. Forest conditions are expected to change because of unsuitable climatic conditions, insects and pathogens and new animal species (reviewed by Gauthier et al. 2014). Effects of global change on tree species and forest ecosystems could be positive or negative. These changes directly affect processes such as seed germination, seedling establishment, and forest tree growth and survival; in the long term, then can alter forest composition, structure and productivity. Global change will also have indirect effects on natural disturbance regimes by modifying the frequency of fires, windstorms, and other extreme events. Moreover, the expected rate of these changes will be faster than the capacity of trees to adapt.

Animal species limited by cold temperatures or snow depth could increase their population size or expand their range toward new suitable habitats. Drought could also increase the risk of insect outbreaks. These new interactions could affect processes in forest ecosystems (Frelich et al. 2012). For

example, increased seed predation by new animal species could affect the regeneration of certain plants or trees, and browsing preferences of more abundant deer populations could favor recalcitrant understory layers.

The portfolio approach defined by Millar et al. (2007) is often proposed to manage forests in the face of uncertainty. These authors propose a conceptual framework for managing forest ecosystems under the assumption that future environments will differ from the present. They recommend choosing strategies that can adapt to different situations. These adaptive strategies include options to favor resistance (to forestall impacts and protect high-value resources), resilience (to improve the ecosystem's capacity to return to desired conditions after disturbances) and response (to facilitate an ecosystem's transition from current to new conditions, hereafter referred to as "transition"). In general, for a given territory, a cautious approach would be to opt for a diversity of adaptive strategies.

Overall, we want healthy, resilient forests that can deal with global change. Yet, the changing environment itself is hard to predict. Over the last decade, Québec policy has tended toward a natural disturbance-based or "coarse filter" approach to maintain biodiversity and resilience in forest ecosystems (Kuuluvainen and Grenfell 2012).

We will use the example of the temperate mixedwood forest zone in Québec (between the 47th and 48th parallels) to develop this idea. This zone is actually the ecotone between the temperate and the boreal forests, in which both temperate and boreal species coexist. Stand-replacing disturbances such as fire have shaped the mixedwood forest according to 200- to 400-year cycles (Boucher et al. 2011), with moderate and light disturbances (e.g. spruce budworm (*Choristoneura fumiferana* [Clem.]) outbreaks, windthrow and natural senescence) occurring between catastrophic disturbances. This has contributed to fashioning a much diversified landscape — a mosaic of stands with different compositions, ages and structures.

The management framework in Québec aims to maintain a stand matrix with target proportions of 4 age classes (regeneration, intermediate, mature and old-growth) that closely mimic natural landscapes. For example, an average preindustrial landscape of the western mixedwood forest had 10% of its area in regeneration (<15 years), 32% as intermediate stands (16–80 years), 31% as mature stands (81–200 years) and 27% as old-growth stands (>200 years) (Boucher et al. 2011). Historical cuts have drastically reduced the representation of mature and old-growth stands and increased that of regenerating and intermediate stands. To reverse this trend, we want to actively conserve older stands with silvicultural systems using partial cuts and modalities that maintain structural attributes. Managers of public forests are required to maintain one third of the preindustrial proportions of mature and old-growth stands on 80% of the territory. The idea is not to reproduce the landscape as it was 200 years ago, but to reduce the gap between unmanaged and managed forests.

The choice of the silvicultural system has major implications on stand structure and structural complexity. Yellow birch–conifer stands are a dominant forest type in the temperate mixedwood, with a disturbance regime characterized by partial mortality, natural senescence and spruce budworm outbreaks. Silvicultural systems such as the continuous cover irregular shelterwood and the hybrid single-tree and group selection cutting could emulate this disturbance regime (Raymond et al. 2009). Balsam–fir conifer stands, another important forest type, are typically harvested by clearcutting and its variants. We are currently testing alternatives, such as an irregular shelterwood system, to emulate the effects of cyclic spruce budworm outbreaks.

Beyond the coarse filter approach, it may prove important to address finer biodiversity issues by adding certain modalities to existing treatments or silvicultural scenarios. For example, in the yellow birch–conifer stands, we can successfully establish yellow birch (*Betula alleghaniensis* Britton), balsam fir (*Abies balsamea* [L.] Mill.) and red maple (*Acer rubrum* L.), but red spruce (*Picea rubens* Sarg.) is much more difficult to regenerate when it is not present as advance regeneration prior to cutting. We are currently testing enrichment planting in harvest gaps with the goal of maintaining this historically important stand component. We are also investigating whether the retention of snags and legacy trees can address the issue of deadwood decline in partial cuttings (Angers et al. 2005) and maximize chances of maintaining forest ecosystem diversity and functions.

The intermediate age class typically comprises second-growth stands that are transitioning between the early- and late-succession stages. These stands often contain larger proportions of hardwoods than the reference for similar site conditions. When planning management according to future changing conditions, our goal could be to favor diversity (by maintaining or increasing the conifer component) and to increase complexity. Enrichment, if needed, could be done with species or provenances adapted to the future climate. With younger stands, we can seize opportunities to improve resilience and transition using silvicultural treatments such as the extended irregular shelterwood (to increase structural complexity), regular shelterwood (e.g. Prévost and DeBlois 2014) and commercial thinning.

Since young, regenerating mixedwood stands are likely to experience environmental changes during most of their existence, it may be worth investing more in transitional approaches. Diversity could be key to maintaining their mixedwood character, as it contributes to decrease the risk that a pest kills the majority of trees. Another sound strategy could be to keep the most vigorous trees that would be adapted to future climate conditions. Mixed precommercial thinning, also experimented in Québec, could offer benefits from both ecological and wood production perspectives. We should also investigate possibilities for mixed-species plantations with species or provenances adapted to future climates. However, much research is still needed before these are applied to a large scale, and caution is recommended regarding assisted migration (Ste-Marie 2014).

As forest managers, we know that forest conditions could change because of pests, invasive plants, unsuitable climatic conditions and migration of new animal species. Overall, although some change is tolerable, we aim to maintain resilient forest ecosystems by working to maintain functional processes and to promote biodiversity. Our general strategy of adaptation should focus on integrating options that favor resilience in older stands, adaptation in intermediate stands and transition in younger stands.

As take-home message, 3 keywords characterize forest management in a changing environment: diversity, resilience and transition. Diversity will reduce the risk of negative interactions between insects, pathogens and animals and forest ecosystems. Resilience will help the most complex stands cope with and recover from stressors. Transition options should help young stands evolve under changing conditions. Nevertheless, we should not forget to diversify management and silviculture at the landscape scale. Silviculture, this old discipline of forest science, remains a great tool to achieve management objectives. This time, it could not only help our forests cope with a changing environment, but it could also contribute to their active conservation.

ACKNOWLEDGEMENTS

Many thanks to Alejandro Royo, Yan Boucher and Daniel Dumais for their advice on the content of this presentation.

REFERENCES

Angers, V.A., Messier, C., Beaudet, M., and Leduc, A. 2005. Comparing composition and structure in old-growth and harvested (selection and diameter-limit cuts) northern hardwood stands of Quebec. Forest Ecology and Management 217: 275–293.

Boucher Y., Bouchard, M., Grondin, P., and Tardif, P. 2011. Le registre des états de référence : intégration des connaissances sur la structure, la composition et la dynamique des paysages forestiers naturels du Québec méridional. Ministère des Ressources naturelles et de la Faune, Direction de la recherche forestière. Mémoire de recherche forestière nº 161. 21 p. https://www.mffp.gouv.qc.ca/publications/forets/amenagement/registre-etats-reference.pdf.

Gauthier, S., Bernier, P., Burton, P.J., Edwards, J., Isaac, K., Isabel, N., Jayen, K., Le Goff, H., and Nelson, E.A. 2014. Climate change vulnerability and adaptation in the managed Canadian boreal forest. Environmental Reviews 22(3): 256–285.

Frelich, L.E., Peterson, R.O., Dovčiak, M., Reich, P.B., Vucetich, J.A., and Eisenhauer, N. 2013. Trophic cascades, invasive species and body-size hierarchies interactively modulate climate change responses of ecotonal temperate–boreal forest. Philosophical Transactions of the Royal Society of London B: Biological Sciences 367(1605): 2955–2961.

Kuuluvainen, T., and Grenfell, R. 2012. Natural disturbance emulation in boreal forest ecosystem management - theories, strategies, and a comparison with conventional even-aged management. Canadian Journal of Forest Research 42: 1185–1203.

Millar, C.I., Stephenson, N.L., and Stephens, S.L. 2007. Climate change and forests of the future: managing in the face of uncertainty. Ecological Applications 17(8): 2145–2151.

Prévost, M., and DeBlois, J. 2014. Shelterwood cutting to release coniferous advance growth and limit aspen sucker development in a boreal mixedwood stand. Forest Ecology and Management 323: 148–157.

Raymond, P., Bédard, S., Roy, V., Larouche, C., and Tremblay, S. 2009. The irregular shelterwood system: review, classification, and potential application to forests affected by partial disturbances. Journal of Forestry 107(8): 405–413.

Ste-Marie, C. 2014. Adapting sustainable forest management to climate change: a review of assisted tree migration and its potential role in adapting sustainable forest management to climate change. Canadian Council of Forest Ministers, Climate change task force, Ottawa, Ontario. 14 p.

KEYNOTE
ENVIRONMENTAL CHANGE AND NORTHERN HARDWOOD ECOSYSTEMS: RECENT OBSERVATIONS FROM HUBBARD BROOK

Tim Fahey

Cornell University, G16 Fernow Hall, Ithica, NY, 14853 USA tjf5@cornell.edu

The 3,160 hectare Experimental Forest is dedicated to long-term forest and stream ecosystem studies. Photo: USDA Forest Service. www.hubbardbrook.org

ABSTRACT

The northern hardwood forest ecosystem at Hubbard Brook Experimental Forest in New Hampshire is responding to a suite of rapid environmental changes. Air temperature and precipitation are steadily increasing, and the depth and duration of snowpack decreasing. After a century of soil base cation depletion by acid rain, deposition of strong-acid anions has rapidly declined in recent years. Ecosystem monitoring and field experiments demonstrate a variety of consequences of these environmental changes for forest ecosystem dynamics. More frequent soil freezing associated with declining snow is damaging fine roots with likely consequences for tree nutrient acquisition. A lengthening of the vernal window, the time between snowmelt and leaf out, is occurring. White pine and red oak are colonizing the understory in the Hubbard Brook valley where they did not occur until recently. Surprisingly, balsam fir and red spruce are increasing in abundance. Experimental restoration of soil calcium stimulated recovery of the health and productivity of the forest. This treatment also has induced a pronounced decline in fine root biomass and the mass of the forest floor soil horizons, the exact opposite of observations from a northern hardwood forest treated with 3-times higher levels of calcium. We anticipate still more radical changes as anthropogenic effects accelerate.

WHY STATE FACTORS AND OTHER METRICS OF BIODIVERSITY CAN EXPLAIN MORE THAN SPECIES RICHNESS ABOUT CARBON STORAGE

David Hooper, Carol Adair[(1)], Alain Paquette, and Jarrett Byrnes

[1)] *Corresponding author: University of Vermont, 85 Carrigan Dr. Burlington, VT 05405 USA*
carol.adair@uvm.edu

ABSTRACT

Evidence suggests that increasing plant diversity increases rates of ecosystem primary production and plant carbon (C) stocks. However, translating these observations into diversity effects on whole ecosystem C storage also requires understanding ecosystem controls on decomposition. We explored the roles of climate, topography, stand age, and plant traits and diversity, on carbon storage in temperate and boreal forests of Québec. We tested effects of abiotic factors alone and in combination with either diversity, community-weighted mean (CWM) plant functional traits, or both, on live tree C, standing dead C, organic horizon C, and total C. Abiotic state factors alone explained much of the landscape-scale variance in C storage, with different C pools responding to different variables, as expected. Similarly, CWM plant functional traits were strong predictors for all C pools, but the traits relevant for live tree C differed from those relevant for litter layer C. While diversity metrics also explained some additional variance, they were never the best biotic predictors for any forest carbon pool; in several cases, diversity had negative effects on litter layer C. Our results have several implications. First, at landscape scales, BEF studies need to integrate mechanisms from plot-scale research with other known drivers of ecosystem processes. Second, where ecosystem services result from multiple different processes, no simple relationship may exist with any one biological metric - whether functional traits or diversity. Finally, moving beyond the expediency of species richness will help us better understand the mechanistic effects of diversity on ecosystem processes and services.

30 YEARS OF FOREST CONVERSION IN THE NORTHEAST: HISTORICAL PATTERNS AND FUTURE PROJECTIONS

Alison Adams[(1)], Jennifer Pontius[(2)], Gillian Galford[(1)], Scott Merrill[(3)], David Gudex-Cross[(3)]

[(1)]University of Vermont & Gund Institute for Ecological Economics, 617 Main St., Burlington, VT 05401, USA, alison.adams@uvm.edu , gillian.galford@uvm.edu

[(2)]University of Vermont & US Forest Service Northern Research Station, 81 Carrigan Dr., Burlington, VT 05405, USA, jennifer.pontius@uvm.edu

[(3)]University of Vermont, 81 Carrigan Dr., Burlington, VT 05405, USA

scott.c.merrill@uvm.edu , david.gudex-cross@uvm.edu

ABSTRACT

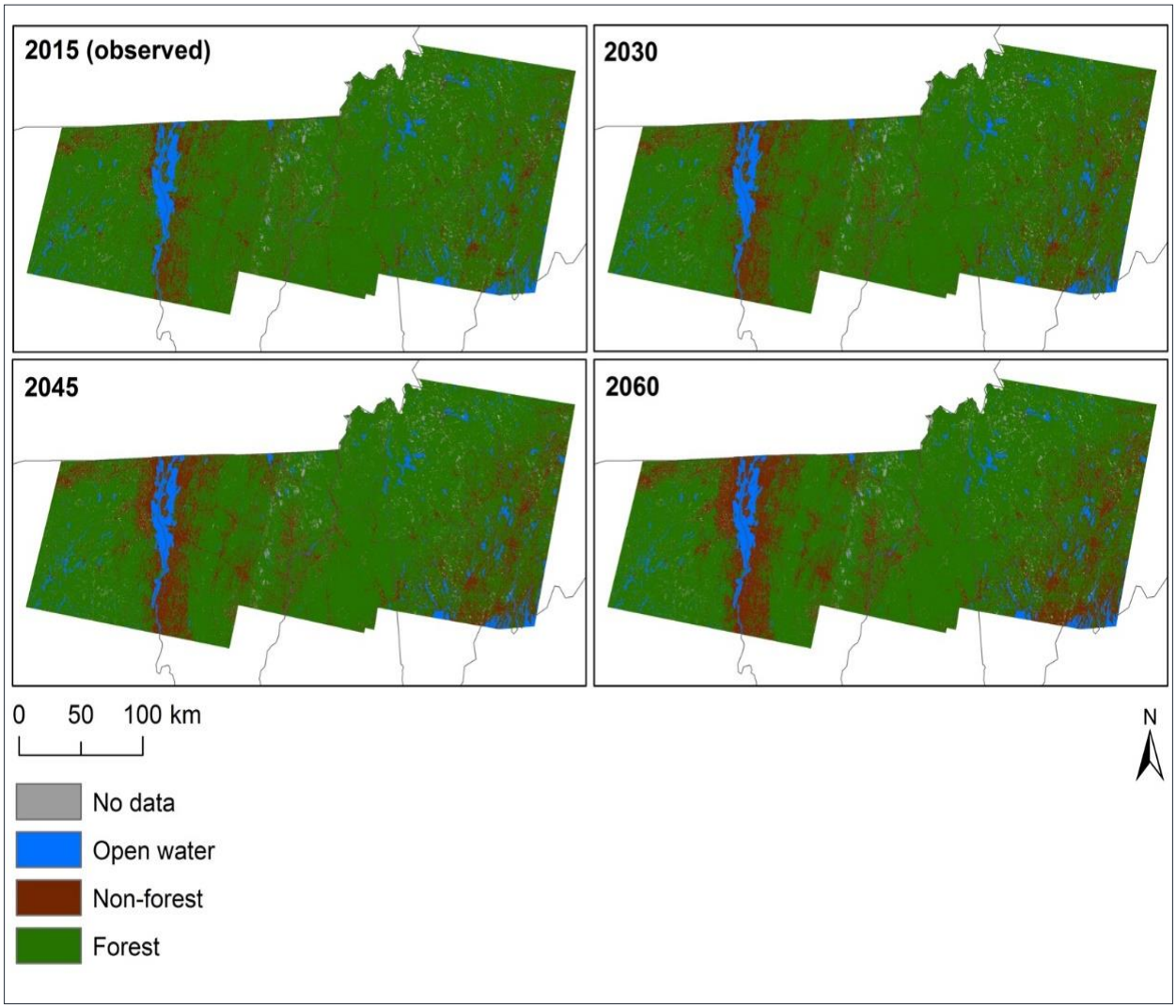
Land use and land cover across the northeastern United States has changed dramatically over the past century. While these changes are highly visible to land managers and planning professionals on a local level, regional information on the nature and extent of these changes has been limited. Thanks to the wealth of historical satellite imagery that has recently become freely available, we are now able to look, with sufficient temporal resolution (5 year intervals from 1985 to 2015), at the patterns and rates of land cover change across the Northeast. In this study we utilized recently-developed maps of land cover in the Northeast to quantify changes in the landscape over the past thirty years, looking particularly at transitions to and from forest. This information is critical to inform adaptive forest management in the face of increasing development and parcelization, as well as converging stress agents across the region. Using Dinamica EGO, a sophisticated spatial modeling platform, we identified significant drivers of historical change and simulated future changes in land cover. Here we present historical and projected changes in forest pattern and extent for the northeastern US from 1985 to 2060.

Initial results indicate that forest cover was lost at a rate of ~0.4% per year between 1985 and 2000 but rebounded between 2000 and 2015 as development pressures decreased with the slowing economy. However, fragmentation of forests increased consistently over the historical study period, even when forest cover was stable. Applying this model across the region shows a high probability of conversion

KEY FINDINGS

- Projected forest area decreased for all time periods.
- All measures of forest fragmentation increased in projected maps.
- Development appears to be a primary driver of transition out of forest.

for forests in high population areas, closer to current non-forested areas, on level slopes and at lower elevations, on properties with low participation in conservation programs.



Change in forest and non-forest area in the Northern Forest region. Study area covers US portions of Landsat Row 29, paths 12 - 14.

WHO ARE MAINE'S BEGINNING FAMILY FOREST OWNERS? A HYBRID RESEARCH-OUTREACH STUDY OF NEW LANDOWNERS

Ian Anderson [(1)], Jessica Leahy [(1)]

[1)] *University of Maine, School of Forest Resources, 5755 Nutting Hall, Orono, ME, 04469 USA*
ianblairmayfield.anderson@maine.edu , *jessica.leahy@maine.edu*

ABSTRACT

Family forest owners own 35% of the forestlands in the United States and their numbers are increasing due to intergenerational transfers and land parcelization. A new cohort of beginning family forest owners (BFFO), who have acquired land in the past 5 years, has emerged, many of whom are not engaged in forest stewardship. Stewardship is important because these lands provide vital and, increasingly, limited resources and ecosystem services to the owners and the public. It is difficult for natural resource professionals to engage this cohort because of limited resources and budgets. This research is designed to explore how landowners' confidence and social capital affects their engagement in forest stewardship. We will present preliminary results from a mail survey administered to 1056 BFFOs in Maine. Using the theory of planned behavior and social capital theory, we developed this questionnaire to measure landowners' intentions and confidence to engage in forest stewardship, and also examine how social capital development may improve landowner outreach. We hypothesize BFFOs' confidence and social capital are important variables when explaining family forest owners' decisions to engage in forest stewardship. We will also describe the second phase of our research which will include peer learning workshops for participants and another survey to determine how landowners' engagement, confidence, and social capital changes over time. This research will be useful to natural resource professionals as they continue to develop outreach programs to engage family forest owners in sustainable forest stewardship.

CLIMATE DRIVEN LANDSCAPE-LEVEL CHANGES IN KEY HARDWOOD SPECIES OCCURRENCE AND ABUNDANCE OVER THE LAST THREE DECADES IN FORESTS OF NORTHEASTERN USA

Arun K. Bose[(1)], Aaron Weiskittel, and Robert G. Wagner

[(1)]*Corresponding author: University of Maine, School of Forest Resources, 5755 Nutting Hall, Orono, ME, 04469 USA* arun.kantibose@maine.edu

ABSTRACT

Climate-driven shifts in forest composition have been widely reported, where changes in abiotic conditions have resulted high mortality of sensitive species and disproportionately favored species better adapted to changing conditions. In recent years, a number of studies have reported the dominance of American beech (*Fagus grandifolia*) in understories of hardwood forests of the Northeastern USA. This is the first study to document landscape-level dynamics of understory tree species during the past three decades across the diverse forests of the Northeastern USA. We used Forest Inventory and Analysis data from Maine, New Hampshire, New York and Vermont to assess the influence of biotic and abiotic factors on sapling occurrence probability and relative abundance of four key hardwood species in the region, namely American beech, sugar maple (*Acer sacharum*), red maple (A. rubrum), and birch (*Betula* spp.). Our results suggest the occurrence probability of American beech has increased substantially over the past three decades in the states of New Hampshire, New York, and Vermont; whereas the occurrence probability of three other hardwood species has decreased. Consequently, a clear shift in species composition is currently happening in hardwood forests with uncertain consequences for the ecosystems structure and function. Abiotic factors were superior to biotic factors in discriminating beech occurrence probability and abundance against three other hardwood species. Positive association between increased precipitation in the Northeast over the last 15 years, and increased beech occurrence probability and relative abundance may suggest a climate-driven shift in species composition in forest understories of the Northeastern USA.

GENE CONSERVATION AND RESTORATION OF RED SPRUCE IN THE SOUTHERN APPALACHIANS

John R. Butnor[(1)] , Kurt H. Johnsen, Barbara Crane, Christopher A. Maier

[(1)] *Corresponding author: Southern Research Station, USDA Forest Service, 85 Carrigan Dr. Burlington, VT 05405 USA jbutnor@fs.fed.us*

ABSTRACT

Red spruce (*Picea rubens*) populations in the southern Appalachians (Tennessee, North Carolina, Virginia) are disjunct from larger northern populations in New York, Vermont, New Hampshire, Maine and Canadian Maritime provinces. Due to heavy logging and subsequent severe fires in the early 20th century, and now due to invasive pests, it has been estimated that there has been a >90% decline in spruce-fir forests in the southern Appalachians. The remaining red spruce populations are highly fragmented. Red spruce is restricted to high elevations in the south and has a high potential to become maladapted with future climate change. Currently, seed for restoration and gene conservation is collected on ad-hoc basis in readily accessible locations in "good seed years". We are developing a more comprehensive inventory of red spruce seed from a range of latitudes and elevations across the eastern United States. Although our work will be range wide, the initial efforts will be concentrated in the southern Appalachians. We will develop a GIS data base to map seed collections. Stand characteristics will be input and then climate data will be overlaid. These data will be used to fill in the gaps of seed availability in terms of latitude, longitude and elevation. We will conduct genecology research to assess if red spruce is a genetic generalist or specialist. If the latter, information on its adaption with respect to micro-climate will be critical for gene conservation, restoration and, perhaps, assisted migration of red spruce in light of climate change.

UNDERSTANDING ATTITUDE STRENGTH INDICATORS TO PREDICT SOCIAL ACCEPTABILITY OF MANAGEMENT INTERVENTION OF INVASIVE INSECTS IN THE NEW ENGLAND FOREST.

Ariana M. Cano[(1)], Walter F. Kuentzel and Kimberly F. Wallin

[(1)] *Corresponding author: University of Vermont, Rubenstein School of Environment and Natural Resources, 85 Carrigan Dr. Burlington, VT 05404,* USA *acano3@uvm.edu*

ABSTRACT

Many biologists argue that the threat of invasive insects is one of the most pressing environmental issues of our time. Endless research presents the threat and risk they pose to the New England forest and the high demand for management and policies to prevent drastic changes. However forest landowners do not share this concern, instead many find this issue to be too complex for their consideration. This study focuses on understanding individuals' attitude towards invasive insects, their concern about invasive insects as an environmental issue and social acceptability of different management practices.

A mailed survey was distributed to forest-owners in the New England region in towns that are either infested, threatened, or non-threatened by HWA, EAB, or ALB. Survey participants were asked about their preferences in a series of questions composing different areas of attitude strength. We hypothesized no significant difference among stratified groups, and instead individuals will show little concern about this issue; making social acceptability of management more difficult to address.

The study findings summarize the different ways in which forest landowner attitude strength differs in response to invasive insects. Also, it shows that there are no significant differences between the different groups surveyed, and their social acceptability to different management practices. To the contrary of biologists' belief, individuals seemed to not be as concerned and alert about managing for invasive insects.

PRIVATE FORESTS, PUBLIC BENEFITS: ECOSYSTEM SERVICES FROM FAMILY FOREST LANDS IN THE USA

Jesse Caputo[(1)], Brett Butler[(2)]

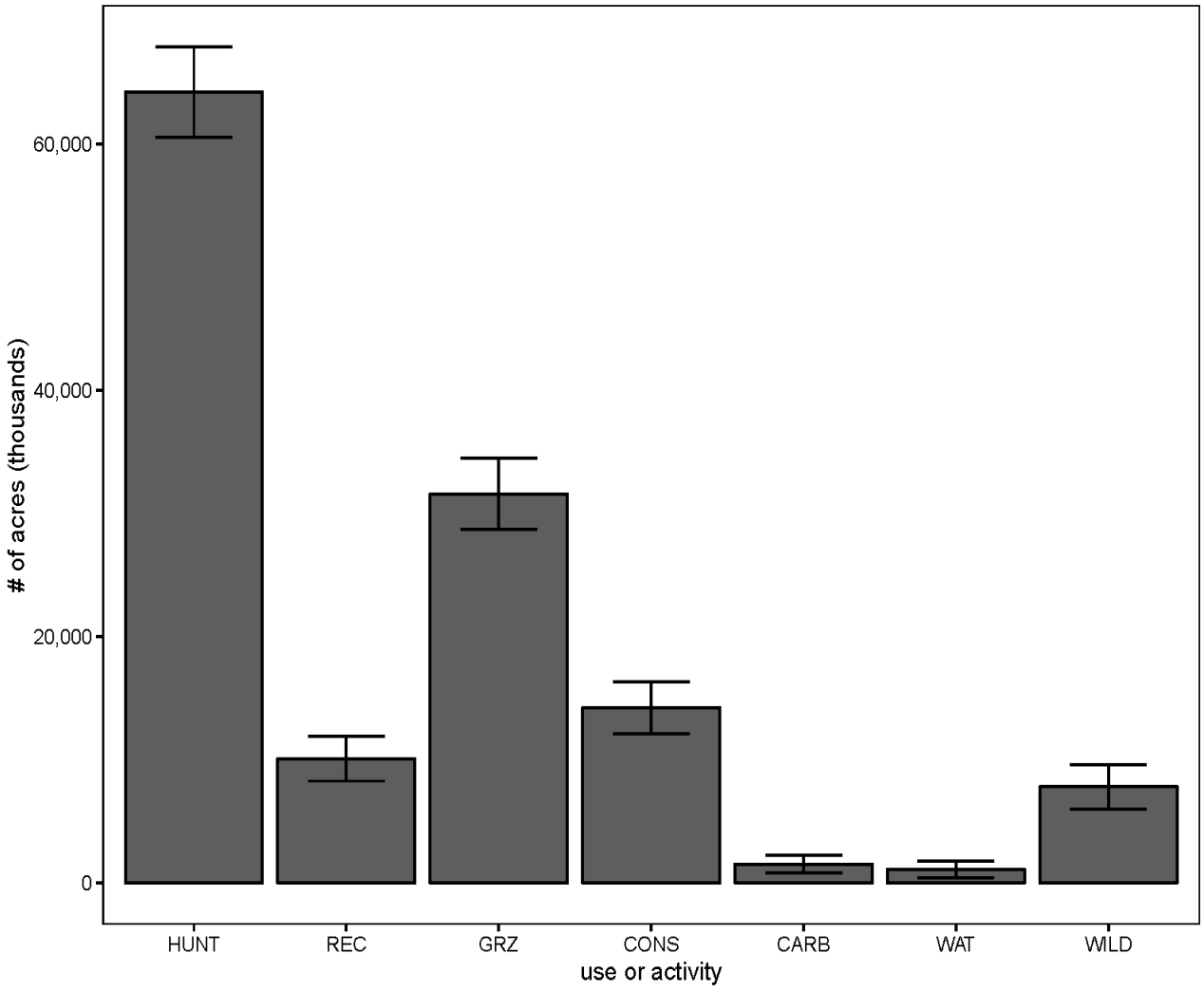
[(1)]Family Forest Research Center, University Of Massachusetts Amherst, 160 Holdsworth Way, Amherst, MA, 01003, USA, jessecaputo@eco.umass.edu
[(2)]USDA Forest Service, 160 Holdsworth Way, Amherst, MA, 01003, USA bbutler01@fs.fed.us

ABSTRACT

Individuals and families collectively own more than 290 million acres of forest and woodland in the USA, comprising greater than 35% of all U.S. forestland. Using data from the USDA Forest Service's National Woodland Owners Survey (NWOS), we provide insight into the extent to which ecosystem services are being supplied by family forest lands and the beneficiaries of those services. Approximately half of family forest lands (>159 million acres) belong to ownerships providing one or more provisioning services, including wood products, non-timber forest products, and animal fodder. With the exception of logs, provisioning services are more commonly reported as being enjoyed directly by owners or their associates, as opposed to being sold through traditional markets. Similarly, while more than half of family forest lands are owned by those who have provided recreational opportunities to friends and family, owners who report recreational services being supplied to the general public (for sale or for free) collectively represent fewer than 30 million acres. The supply of regulating and supporting services is strongly linked to the maintenance of long-term forest cover. The owners of greater than 80% of family forest lands report a desire to maintain the forested condition of their land, whereas a much smaller percentage of these owners (owning < 14 million acres) have entered into conservation easements or have collected money for conservation purposes. Even less acreage belongs to owners reporting leasing land or collecting money for wildlife habitat/biodiversity (< 8 million acres), carbon storage or sequestration (< 2 million acres), or public water supply protection (< 2 million acres).

KEY FINDINGS

- Individuals, families, and trusts own more than 35% of U.S. forestland.
- Family forests provide a wide variety of ecosystem services and products.
- Many services are primarily enjoyed by landowners and close associates.



Estimated area of family forest and woodland ownerships (10+ acres) which have leased forest land or collected money for use of forest land by use or activity, United States, 2011-2013. Error bars represent two standard errors.

HUNT = hunting,

REC = recreation (other than hunting),

GRZ = to graze / pasture livestock,

CONS = land conservation,

CARB = carbon capture / sequestration, WAT = public water supply protection,

WILD = wildlife habitat / biodiversity.

WABANAKI YOUTH IN SCIENCE (WAYS): A TRIBAL MENTORING AND EDUCATIONAL PROGRAM FOCUSED ON DEVELOPING YOUNG NATURAL RESOURCE PROFESSIONALS

Tish Carr[(1)], Laura S. Kenefic[(2)] and Darren Ranco [(1)]

[(1)]*Wabanaki Center, University of Maine,* 5717 Corbett Hall, Room 208, Orono, Maine 04469-5724 USA *tish.carr@maine.edu*

[(2)]*U.S. Forest Service, Penobscot Experimental Forest, 686 Government Road, Bradley, ME USA 04411, lkenefic@fs.fed.us*

ABSTRACT

The Wabanaki Youth in Science (WaYS) program, funded by the National Science Foundation and administered by the Wabanaki Center at the University of Maine, provides mentoring and training opportunities for Native American youth in life sciences. This program, which was motivated by a shortage of young natural resource professionals to manage tribal lands in Maine, uses a multifaceted, multi-year approach to recruit and retain Native youth in science fields. Key components include (1) summer camp and seasonal mini camps, (2) traditional ecological knowledge programs at tribal teen centers and Boys & Girls Clubs, and (3) internships with cultural resource and natural resource mentors. A defining characteristic of the program is the integration of knowledge from cultural resource and natural resource mentors. This approach helps students develop an understanding of contemporary natural resource problems informed by their community and culture, leading to greater relevance and persistence in science. In addition, internships with tribal and non-tribal institutions (such as on ongoing habitat restoration project with the U.S. Forest Service) provide pathways to employment and bring diverse perspectives to natural resource management. In the first three years of the WaYS program, the number of Wabanaki youth enrolled in science fields at the University of Maine increased by 15%. We suggest the longitudinal and multifaceted approach used in the WaYS program (i.e., camps, community outreach, and internships with cultural resource and natural resource mentors) as a model for other initiatives aimed at engaging Native youth in life sciences.

EVALUATING THE INFLUENCE OF STEM FORM AND VIGOR ON PRODUCT POTENTIAL, GROWTH, AND SURVIVAL FOR SEVERAL NORTHERN COMMERCIAL HARDWOOD SPECIES

Mark Castle[(1)], Aaron Weiskittel[(2)], Robert Wagner[(1)] and Mark Ducey[(3)]

(1) School of Forest Resources, University of Maine, 201 Nutting Hall, Orono, ME 04469, USA *mark.castle@maine.edu*

(1) School of Forest Resources, University of Maine, 201 Nutting Hall, Orono, ME 04469, USA *aaron.weiskittel@maine.edu*

(2) Department of Forestry and Natural Resources, Purdue University, 715 West State Street, West Lafayette, IN 47907, USA. *rwagner@purdue.edu*

(3) College of Life Sciences and Agriculture, University of New Hampshire, Rudman Hall, 46 College Road, Durham, NH 03824, USA *Mark.Ducey@unh.edu*

ABSTRACT

Northern hardwood species display a wide variety of stem forms and defects which can considerably reduce stem quality and complicate the management objectives of these species. Although commonly cited as limiting factors of hardwood species, the influence of both stem form and damage remain largely unaccounted for in volume/biomass equations or even growth and yield models. In addition, the limited integration of these attributes into growth and yield applications has left the efficacy of current tree classification systems used to manage these species untested. The purpose of this study was to determine the influence of stem form and damage on product potential, growth, and survival among several prominent northern commercial hardwood species and present a revised framework for a tree classification system. Using data collected across several sites in Maine, New Hampshire, and New Brunswick, a series of models were developed to quantify potential sawlog recovery, periodic annual increment, and probability of survival across trees of varying stem form and vigor using a classification system developed by the Northern Hardwood Research Institute (NHRI). The results indicated that a classification system with four stem form categories accounting for trees with single straight stems, sweep, multiple stems, and significant forks along with two classes characterizing damage severity could be used to differentiate between hardwood species of varying stem quality and vigor in the Northeast region.

MANAGEMENT INFLUENCES FUNCTIONAL COMPOSITION AND DIVERSITY IN NORTHERN HARDWOOD AND MIXED-CONIFER FORESTS IN MAINE AND NEW HAMPSHIRE, USA

Miranda T. Curzon[(1)], Anthony W. D'Amato[(2)], Shawn Fraver[(3)], Brian J. Palik[(4)], John B. Bradford[(5)], Jane R. Foster[(1)], Alessandra Bottero[(6)], Kelly E. Gleason[(5)]

[(1)]Department of Forest Resources, University of Minnesota, 1530 Cleveland Avenue North, Saint Paul, MN 55108, USA, mcurzon@umn.edu, jrfoster@umn.edu
[(2)]Rubenstein School of Environment and Natural Resources, University of Vermont, 81 Carrigan Drive, Burlington, VT 05405 USA, awdamato@uvm.edu
[(3)]School of Forest Resources, University of Maine, Orono, ME 04469, USA, shawn.fraver@maine.edu
[(4)]USDA Forest Service, Northern Research Station, 1831 Hwy 169 E., Grand Rapids, MN 55744, USA, bpalik@fs.fed.us
[(5)]US Geological Survey, Southwest Biological Science Center, Flagstaff, AZ, USA,jbradford@usgs.gov, kgleason@usgs.gov
[(6)]Swiss Federal Institute for Forest, Snow, and Landscape Research, Zürcherstrasse 111, CH-8903 Birmensdorf, Switzerland, alessandra.bottero@wsl.ch

ABSTRACT

Concern about global environmental change and associated uncertainty has given rise to greater emphasis on building adaptive capacity in forest ecosystems. Greater diversity is generally believed to contribute to resilience and adaptive capacity, but that relationship is nuanced and varies widely across ecosystems and scales.

Using a combination of historic inventories and dendrochronological techniques, we examined the effects of conventional management approaches on plant traits and functional diversity in northern forests located in New Hampshire and Maine, USA. Two harvest treatments (typical for each forest type) and an untreated control were replicated three times at each site. Community-weighted trait means (leaf mass per area, specific gravity, maximum height, seed mass, drought tolerance, shade tolerance, and flood tolerance) and standard functional diversity indices were quantified based on observed standing biomass in 2010 allowing comparisons of stands managed with different silvicultural systems since the 1950's. Additionally, trait means and functional diversity measures were estimated for stand biomass increment each year 1984-2009.

Few differences in functional diversity emerged between treatments in the northern hardwood forest, but in mixed-conifer forest, stands managed with selection had lower functional diversity relative to those managed with the shelterwood method. In the absence of disturbance (i.e. in control stands) functional diversity remained stable over time. Selection decreased drought tolerance relative to even-aged systems in both forests. Overall, our results support hypotheses that regeneration methods influence functional composition and diversity, both potentially related to forest ecosystem resilience. Lastly, observed relationships between annual, trait-based growth and climate variables suggest functional composition may influence climate-growth responses in these forests.

BOREAL FOREST FRUIT SHRUBS CULTIVAR TRIALS AND PROPAGATION FOR THE DIVERSIFICATION OF FRUIT PRODUCTION ON THE NORTH SHORE REGION OF QUEBEC, CANADA

Ève-Catherine Desjardins

Centre d'expérimentation et de développement en forêt boréale (CEDFOB),
537, boulevard Blanche, Baie-Comeau, Québec, Canada,
eve-catherine.desjardins@cedfob.qc.ca

ABSTRACT

Goals

- Select and test on the north shore region of Quebec at Longue-Pointe-de-Mingan (50°18'12"N; 64°11'25"O), Pointe-aux-Outardes (49°5'13"N; 68°23'16"O) and Sacré-Coeur (48°14'51"N; 69°51'57"O) within a permaculture system* hardy and productive cultivars (quantity and quality of fruit).
- Improve cutting techniques of these shrubs in collaboration with a local nurseryman.
- Support nurseries and small fruit growers in the development of novel boreal forest fruit crops including saskatoons (*Amelanchier* spp.), haskaps (*Lonicera caerulea*), red currants, gooseberries and jostaberries (*Ribes* spp.), lingonberries (*Vaccinium vitis* idea) and highbush cranberries (*Viburnum edule*).

* *The permaculture system is characterized by crop self-sufficiency and is low input. Field preparation consists of hilling and mulching, in this case with leaves, freshly chipped branches and composted aspen bark.*

Permaculture installation at Longue-Pointe-de-Mingan and small fruits cutting trials.

Results

The best *Ribes* (yields, fruit quality, growth and disease and insect susceptibility) were Hinnomaki red, Red Lake, White Pearl and Jostaberry. With the exception of the Longue-Pointe-de Mingan site (the northernmost site) the gooseberries were attacked (up to complete defoliation) by the sawflies, *Nematus ribesii* and *Pristiphora rufipes*. It is possible that their distribution does not extend as far as the northernmost site giving this site a large advantage.

The best performing haskap was Indigo Treat. However, this cultivar is susceptible (fruit punctures) to the honeysuckle moth *Ypsolopha dentella*. Flowers of the very early haskap cultivars (Blue Nova and Blue Sky) suffered from late spring frosts and these cultivars are therefore not advised for the north shore unless a wood chip mulch is used which delays the flowering period.

Among the saskatoons the cultivars Drapeau ll and Martin were the best performing. The main problem encountered was with birds eating the ripe fruits.

The cutting trials allowed the adaptation of existing protocols and the formation of a working team including a local nursery which is willing to provide growers interested in developing these new fruits crops with plants. The fruiting period of these five small fruits (haskaps, saskatoons, gooseberries, jostaberries and red currants) stretches from early July until the beginning of September. The complementarities of certain cultivars permit an extension of the harvest period and favors workforce retention in isolated regions.

CONTINUED EXPANSION OF THE VERMONT MONITORING COOPERATIVE'S FOREST HEALTH MONITORING NETWORK

James Duncan[(1)], Kirsti Carr, Diana Gurvich, Rebecca Rossell, John Truong and Jennifer Pontius

[(1)]*Corresponding author: Vermont Monitoring Cooperative and Rubenstein School of Environment and Natural Resources, University of Vermont, 705 Spear St, South Burlington, VT 05403 USA*
james.duncan@uvm.edu

ABSTRACT

In 1991, the Vermont Monitoring Cooperative and the Vermont Department of Forests, Parks and Recreation began a statewide forest health monitoring network, designed to uncover important relationships, changes, and stressors impacting Vermont's forested landscape. The plots were initially located in intensive study sites on Mt. Mansfield and in the Lye Brook Wilderness, and were surveyed annually. In the last three years, the network was expanded from 14 to over 45 plots by co-locating with other forest health monitoring efforts such as the USFS Forest Inventory and Analysis, the North American Maple Project, and others. This expands and intensifies forest health assessment efforts in the state, sampling a wider range of biophysical regions and a more representative cross-section of Vermont's forests with an enhance methodology. The result of this expanded network is a fuller set of data available for evaluating long-term trends in forest health in the state. In addition, data was collected in 2016 using the Foresters for the Birds methodology, providing an additional resource for characterizing these long-term monitoring plots, which will be presented here.

INTRODUCING A MULTI-CRITERIA DECISION SUPPORT TOOL FOR MANAGING FORESTS UNDER CLIMATE CHANGE

James Duncan[(1)(2)], Clare Ginger[(1)] and Jennifer Pontius[(1)(2)(3)]

(1) Rubenstein School of Environment and Natural Resources, University of Vermont 85 Carrigan Dr. Burlington, VT 05405 USA james.duncan@uvm.edu , cginger@uvm.edu
(2) Vermont Monitoring Cooperative 705 Spear St, South Burlington, VT 05403 USA
(3)US Forest Service, Northern Research Station 85 Carrigan Dr. Burlington, VT 05405 USA
Jennifer.pontius@uvm.edu

ABSTRACT

Climate change has the potential to alter forest ecosystem composition and processes in Vermont, USA, through direct and indirect pathways. Forestland managers are left with an array of possible factors to consider when attempting to incorporate climate change impacts in management planning, from species range shifts to invasive species risk to wildlife habitat suitability to changes in recreation patterns. Combining and weighting these factors can often mean a time-consuming process of accessing and interpreting output from multiple tools each time a decision needs to be made. We present preliminary work on a new web-based decision support tool that allows users to evaluate customized combinations of objectives under current and future climate conditions. Based on a common spatial grid for the state of Vermont, users can define an area of interest, select from a wide list of modeled outcomes, weight the relevant importance of those outcomes and select one or several climate change predictions to assess. In addition, differences among management alternatives can also be computed for some objectives within the tool. The resulting output is a series of maps showing the overall relative ranking of the landscape for the combination of chosen objectives under different climate change scenarios, as well as accompany summary statistics and figures. These products provide a multi-faceted, spatially explicit ranking of how different portions of the chosen landscape can meet the forest management goals of the user under different climate change scenarios.

A SYSTEMS PERSPECTIVE ON THE SHIFT TO MODERN WOOD HEATING TECHNOLOGY IN THE NORTHERN FOREST REGION

Laura Edling and Cecilia Danks

Rubenstein School of Environment and Natural Resources, University of Vermont 85 Carrigan Dr. Burlington, VT 05405 USA laura.edling@uvm.edu , cdanks@uvm.edu

ABSTRACT

This study takes a systems approach to understanding the complex factors that affect the transition toward local, sustainable energy sources, with a focus on the case of modern wood heat. The research team from the Northern Forest Center, University of Vermont, and University of Maine, Orono is studying the conversion to high efficiency, low emissions, wood pellet technology among households, local businesses and community buildings in the Northern Forest region of New York, Vermont, New Hampshire, and Maine. Collecting data through interviews, surveys, and site visits, the team will identify both the proximal factors that influence the adopters of modern wood heating systems as well as the relationships, leverage points and drivers of the energy system that shape consumer choices. We will analyze the Model Neighborhood Wood Heating Initiative-- a community-based, systemic approach to foster conversion to modern wood heating – and explore synergies and differences with more traditional, state-wide policy incentives. While still in data collection stage, we expect our findings to assist in a holistic understanding of the transition from fossil fuels in the Northern Forest region, and ultimately have theoretical and policy implications for other energy transitions elsewhere.

MANAGING INVASIVE PLANTS ON VERMONT'S STATE LANDS

Molly Elvin[(1)], Heather Ewing, Liz Bourget and Elizabeth Spinney

[(1)] Corresponding author: Vermont Department of Forests, Parks, and Recreation, 1 National Life Drive, Davis 2, Montpelier, VT 05620-3801 USA n elvinm@greenmtn.edu

ABSTRACT

Invasive plant species are non-native plants that cause harm to native ecosystems by displacing native plants and disrupting natural cycles. Invasives can cause a wide range of harms including harm to human health, environmental harm, and economic harm. The southwestern region of Vermont's state forests and parks took the proactive step in 2013 of creating a three-year, grant funded habitat restoration crew to help control invasive species by assessing, managing, and educating the public about the invasives. The crew has educated hundreds of volunteers from schools, churches, and businesses all over Vermont on what invasive species are and what they can do to help control them. Throughout the three years of the habitat restoration crew, they have compiled extensive research and experience on the best ways to control each of the 45 state designated noxious plants which can now be passed on to the public as well as the other regions of Vermont's parks and forests.

TRACKING SUBDIVISION AND PARCELIZATION TO INFORM LAND USE PLANNING, CONSERVATION AND THE MANAGEMENT OF FORESTS IN VERMONT

Jamey Fidel[(1)], Deb Brighton[(2)], Kate McCarthy[(1)], Brian Shupe[(1)], Emma Zavez[(1)]

[(1)]Vermont Natural Resources Council, 9 Bailey Avenue, Montpelier, Vermont 05602 USA
jfidel@vnrc.org

[(2)]Vermont Family Forests, PO Box 254, Bristol, Vermont 05443 USA *debbrighton@myfairpoint.net*

ABSTRACT

When forestland is broken up into smaller parcels from subdivision, the result is typically an increase in the number of landowners and housing units in addition to new infrastructure such as roads, septic and utility lines. Depending on how this development occurs, it can fragment the landscape and negatively affect plant and animal species, wildlife habitat, water quality, and the ability of forests to mitigate the effects of climate change. It can also affect the contiguous ownership and management of forest parcels, and thus the viability of large tracts of forestland to contribute to Vermont's working forest economy.

Research studying parcelization and subdivision trends between 2003 and 2009 demonstrates that while a large percentage of the land in Vermont (71%) is still represented in parcels greater than 50 acres, the trend is that larger parcels are being converted into smaller and smaller parcels (see key findings). The value of land in parcels 50 acres or larger appreciated significantly during this study period shifting from an average value of

KEY FINDINGS

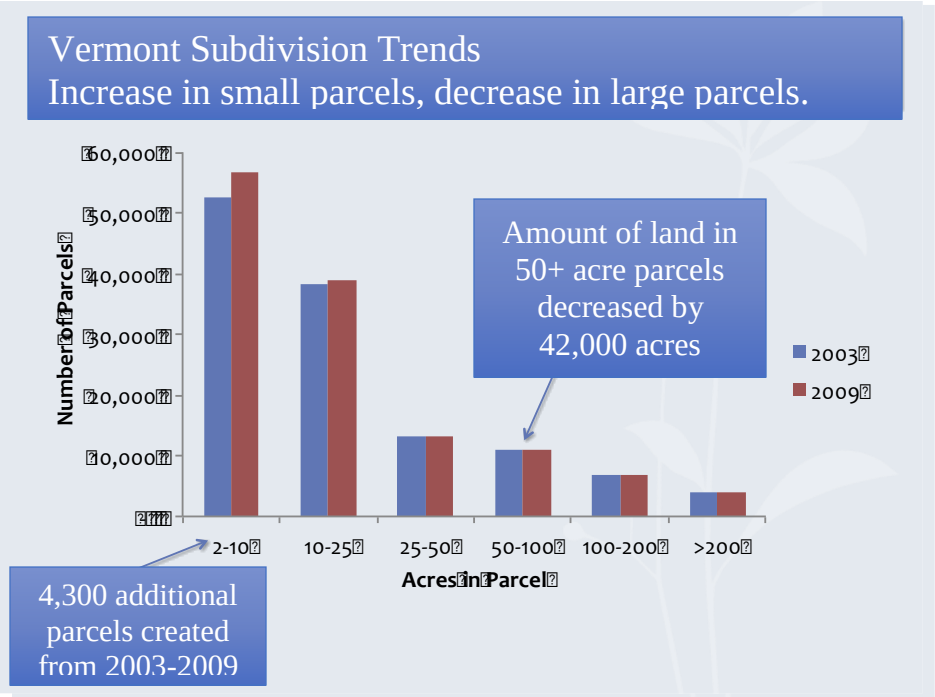
- The amount of land in 50+ acre parcels decreased by 42,000 acres between 2003 and 2009 while 4,300 additional parcels were created in the 2-10 acre category.
- From 2003-2009, 126,000 acres of land went from being undeveloped, to having a house.
- Research in 22 case study towns indicate that subdivision is mostly happening in small increments (2-4 lots at a time). In general, subdivisions of this size are not large enough to trigger statewide review, which means municipal regulations play a major role in guiding subdivision patterns in Vermont.

$930 per acre in 2003 to $1,615 per acre in 2009, putting pressure on forestland owners to hold onto larger parcels of land.

Research in 22 case study towns examined the correlation between subdivision rates and land use regulations from 2002 and 2009. On average, each subdivision resulted in 2-4 lots, and only 1% - 2% of subdivisions in the case study towns were large enough to trigger Act 250, Vermont's statewide process for reviewing and managing the environmental, social and fiscal consequences of major subdivisions and developments. Therefore, municipal regulations play a major role in guiding subdivision patterns in Vermont. Subdivision activity is more likely to occur in rural areas such as rural-residential districts than in conservation oriented zoning districts. This means natural resource features in "default" zoning districts – where most subdivision is happening – may be vulnerable to development unless there are natural resource protection standards in the land use regulations.

Research also demonstrates that subdivision is increasing the number of parcels that are eligible for Vermont's Use Value Appraisal (Current Use) Program, but decreasing the number of acres that are large enough to be enrolled. This means more landowners are enrolling in the Program, while the amount of land that is eligible to be enrolled for conservation is decreasing.

Efforts are currently underway to develop a new statewide database and an on-line data dashboard that will update the subdivision trend information and facilitate the visual inspection, querying and dissemination of parcelization and subdivision data on an annual basis at multiple spatial scales spanning local, regional and statewide levels. This tool will benefit researchers, land management agencies, municipalities, professional planners, regional planning commissions, conservation organizations, natural resource professionals and foresters in their ability to identify and maintain large intact areas of forests.



STUDYING WOOD QUALITY IN THE CONTEXT OF A SPRUCE BUDWORM OUTBREAK IN QUEBEC

Gabriel Fortin

Centre d'expérimentation et de développement en forêt boréale (CEDFOB) Baie-Comeau, QC G5C 2B3, Canada gabriel.fortin@cedfob.qc.ca

ABSTRACT

A spruce budworm outbreak is in progression in Quebec. In the region of the North Shore, defoliation is observed since 2006 and the annual defoliated area is increasing each year. In 2015, 3 754 605ha were defoliated. The defoliation causes growth reduction, mortality as well as loss in wood quality.

The effects of defoliation on wood quality of balsam fir and spruces are studied by our team since 2014 in the North Shore of Quebec. In our studies, the defoliation and the condition of trees were measured. Wood coloration and decay of harvested logs were characterized, as well as chips quality according to three metrics; the humidity, the luminance and the proportion of dark fiber. The quantity of residual wood left in the forest following harvesting, in an operational context, is also measured. These results aim to identify indicators that could predict the quality of the wood to harvest, giving forest companies a predictive tool that could help them with the harvesting management.

FORECASTING CLIMATE CHANGE REFUGIA FOR MONTANE SPECIES: HOW HARVEST AND DISTURBANCE AFFECT SPECIES PERSISTENCE

Jane R. Foster[(1)] and Anthony W. D'amato[(2)]

[(1)] *Department of Forest Resources, University of Minnesota, St. Paul, MN, USA* *jrfoster@umn.edu*
[(2)] *Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, VT* USA *awdamato@uvm.edu*

ABSTRACT

Montane forest species are vulnerable to climate change, challenging land-managers who must prioritize protected areas for conservation. Sub-alpine spruce-fir forests in New England illustrate this challenge. Forests of *Abies balsamea* and *Picea rubens* are predicted to recede to higher elevations as temperatures increase. Warm-adapted species are predicted to expand upward. Yet satellite imagery has shown that the extent of subalpine forests has remained stable or expanded downward over the past 30 years of warming. We hypothesize that movement of the sub-alpine forest boundary is responding more to disturbance dynamics, from wind, harvests and insect outbreaks, than to changes in climate.

We ask how disturbances help or hinder the development of refugia for montane species in the Green Mountains National Forest (GMNF) in Vermont, USA. We simulated future forest conditions using the landscape model LANDIS-II under a combination of four global circulation model (GCM) projections. We tested whether spruce-fir forests shrink as expected and identify where spruce-fir persists as potential climate refugia for conservation.

Growth and establishment of the montane species *A. balsamea* and *P. rubra* were sensitive to the range of GCM projections; increasing or decreasing depending on soil type and topographic position. In spite of this variation in vital rates, total spruce-fir extent proved resistant to projected changes in climate and did not decrease significantly between 2010 and 2100. Fine-scale landscape simulations successfully identified potential climate refugia for montane spruce-fir forests providing an opportunity to direct conservation efforts towards areas with the highest likelihood of success.

OUT OF THE LAB AND INTOTHE FIELD: COMMERCIAL PRODUCTION OF BAKEAPPLE PLANTS

Marie-Claire Gervais [(1)], Sara Kristine Naess[(2)]

[(1)]Centre d'expérimentation et de développement en forêt boréale, 537 boul. Blanche, Baie-Comeau Québec, G5C 2B2 (Canada), marie-claire.gervais@cedfob.qc.ca
[(2)]Centre de recherche Les Buissons, 358 chemin Principal, Pointe-aux-Outardes, Québec, G0H 1M0 Canada kristine.naess@crlb.qc.ca

ABSTRACT

The bakeapple (*Rubus chamaemorus* L.) grows in the peatlands of the boreal forest. In the North Shore region of Quebec, the fruit has been harvested from the forest for centuries and wildcrafting, while not efficient enough for industry development, is still in use today. In order to improve the harvest efficiency and diversify the forestry economy of this region, domestication of non-lignified forest products, such as the bakeapple, is considered.

KEY FINDINGS

- The bakeapple plant adapts well to high density in vitro propagation in low cost commercially available plastic containers suitable for shipping.
- They can be efficiently acclimatized by growers on site in low cost mist chambers using locally available milled peat.

: a: bakeapple plant in vitro; b: bakeapple plant into the field.

The Centre d'expérimentation et de développement en forêt boréale (CEDFOB) is currently working on a project to optimise bakeapple micro-propagation techniques with commercial production in mind. A multidisciplinary team composed of biologists, agronomists, research scientists and plant tissue culture specialists is working to help a group of producers on the Lower North Shore initiate a new small fruits industry based on bakeapple production. There are currently no nurseries producing bakeapple plants. Norwegian bakeapple cultivars are available for import but aside from problems dealing with phytosanitary laws and regulations, these cultivars are not adapted to the climatic conditions of the boreal forest of eastern Canada. With the recent plant breeding work at the Centre de recherche Les Buissons (CRLB) involving native bakeapple clones and the plant tissue culture protocols in development at CEDFOB we are now in a position to contemplate the mass production of bakeapple plants having agronomic potential for industry development. Commercial in vitro propagation could also be used to produce large quantities of bakeapple plants for restoration of cut-over peatlands.

CARBON FORESTRY OPTIONS USING EXOTIC LARCHES IN NORTHERN NEW ENGLAND

Alec Giffen[(1)], Lloyd C. Irland[(2)], David I. Maass[(3)], Brian Roth[(4)]

(1) Togus Rd, Chelsea, ME 04330, USA alecgiffen@gmail.com
(2) 174 Lord Rd, Wayne, ME 04284, USA lcirland@gmail.com
(3) 8 Countryside Ct, Bluffton, SC, 29909, USA dmaass@maine.rr.com
(4) CFRU, University of Maine, School of Forest Resources, 5755 Nutting Hall, Orono, ME 04469-5755, USA brian.roth@maine.edu

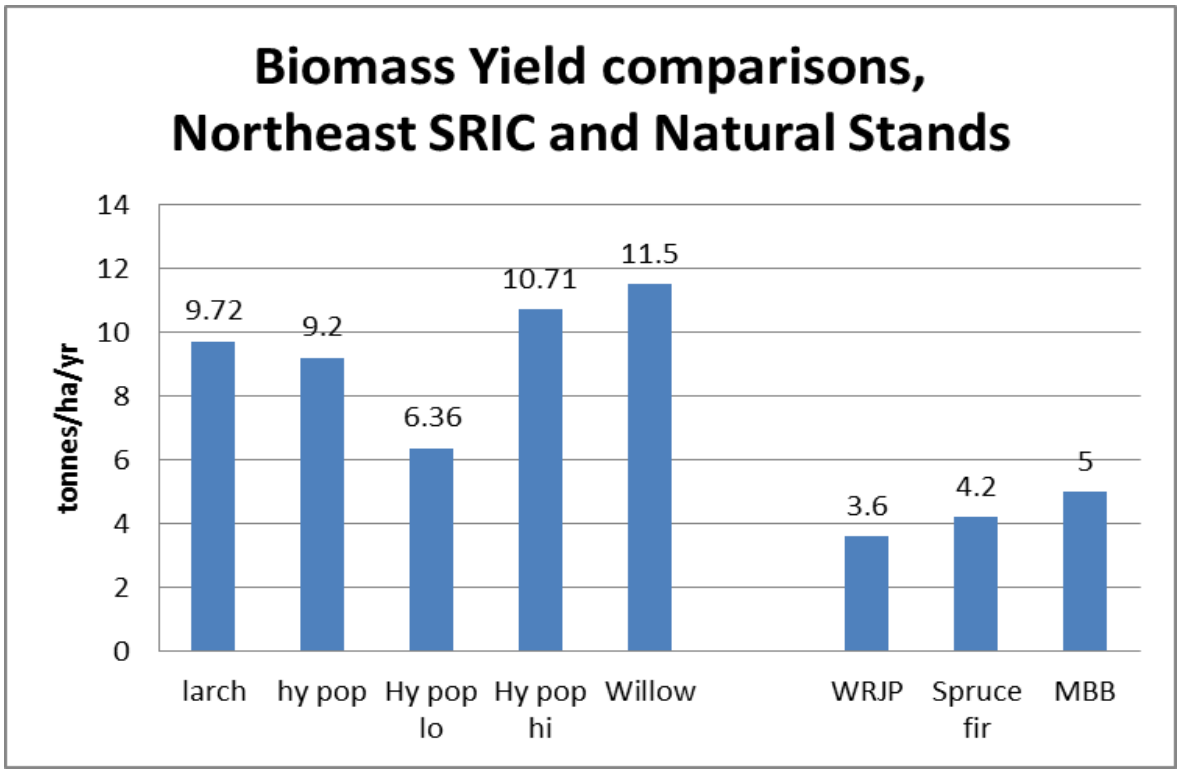
ABSTRACT

Exotic European (*L. decidua*), Japanese (*L. kaempferi*) and Dahurian larches (*L. gmelinii*), and their hybrids, have been planted in numerous small trials and operational plantings in this region. Estimated volume growth rates far exceed what is obtained by native conifers. Stands can reach small sawlog sizes in 16-20 years. In one instance a stand was harvested commercially at age 13. Documented results show that, with only basic management, planted larches can offer another option for carbon forestry in this region. The volume grown can be used for long-lived wood products instead of paper or energy as is expected with other short-rotation intensive culture (SRIC) species being studied in the Northeast. We compare estimated carbon storage results in a 60 year management period using these larches. Forest plantations offer only limited leverage on the regional carbon budget, but we believe larches deserve consideration as one option. Finally, larch leaf litter is nutrient rich and the species can be used in a variety of silvicultural roles.

KEY FINDINGS

- European and Japanese larch growth rates far exceed native conifers
- Larch management is an option for carbon forestry and production of long-lived wood products

Fourteen year old larch plantation, private land, western Maine. D. I. Maass photo.



Estimated carbon storage results in a 60 year management period.

PATTERNS OF NONNATIVE INVASIVE PLANT SPECIES DIVERSITY IN GYPSY MOTH DEFOLIATED FORESTS

Maryna Golivets [(1)], Christopher W. Woodall, and Kimberly F. Wallin

[(1)] *Corresponding author: Rubenstein School Environment and Natural Resources, University of Vermont, Burlington, VT 05405, USA*
mgolivets@uvm.edu

ABSTRACT

Northeastern forests are experiencing a constantly rising level of invasion by nonnative species, which is associated with the increased probability of interactions within the nonnative component of the biota. Here we studied regional patterns of nonnative plant species diversity in forests previously defoliated by a highly invasive insect, gypsy moth (*Lymantria dispar*). We coupled gypsy moth disturbance data available through the Forest Health Monitoring Program of the USDA Forest Service with data on nonnative plant species collected within the Forest Inventory and Analysis (FIA) Program of the USDA Forest Service. Across 10 eastern US states, we selected over 400 FIA plots that ranged in the total number of gypsy moth outbreaks during the last 40 years from 0 to 10. We fitted generalized linear mixed models to nonnative invasive plant species density and presence-absence data. To compare species richness among defoliated and non-defoliated plots, we computed sample-based rarefaction curves. Gypsy moth defoliation had a significant negative effect on presence and species richness of nonnative invasive plants.

DELINEATING RIPARIAN AREAS IN WORKING FORESTS - FIXED WIDTH VERSUS FUNCTIONAL?

Maneesha Jayasuriya, René H. Germain and Eddie Bevilacqua

Department of Forest and Natural Resources Management, State University of New York College of Environmental Science and Forestry, 1 Forestry Drive, Syracuse, New York 13210. USA
ktjayasu@syr.edu, rhgermai@esf.edu, ebevilacqua@esf.edu

ABSTRACT

Riparian management zones (RMZs) are often based on fixed-width buffers, which may result in significant errors as they may or may not represent the actual extent of a functional riparian area. This study in the Catskill region of New York examined the difference in area dedicated to RMZs on first and second order streams using the fixed-width (100ft) versus the functional approach in both the field and at a broader spatial scale using high resolution DEM data. Field sampling was done along six first order streams and three second order streams resulting in a total stream sampling length of 4.187 km (2.6 miles). When comparing the two riparian area delineation methods, there was no significant difference in terms of dedicated land area (11 %) to the RMZ. The digital delineation of the fixed-width and functional-based riparian buffer was conducted across 4,457.42 km^2 (1.1 million acres) of timberland in the Catskill region using 10 randomized 36 million square meter blocks. A total of 397 first order and 139 second order streams/stream segments with a total stream length of 309.23 km (192.15 miles) were analyzed using the two buffering approaches. Generally, the area dedicated to riparian protection was 8% of the timberland area and the fixed-width buffer over-delineated timberlands as riparian along first order streams when compared to the functional based buffer. Therefore a fixed-width buffer may not be ideal for headwaters especially in mature northern hardwood forests and a functional riparian area allocation is more suitable for these streams.

REGENERATION RESPONSES TO MANAGEMENT FOR OLD-GROWTH CHARACTERISTICS IN NORTHERN HARDWOOD-CONIFER FORESTS

Aviva Joy Gottesman and William S. Keeton

Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, VT, USA
aviva.j.gottesman@gmail.com , William.keeton@uvm.edu

ABSTRACT

Forest management practices interact with multiple sources of variability to influence regeneration trends in northern hardwood forests. There is uncertainty whether low-intensity selection harvesting techniques will result in adequate and desirable regeneration. Our research is part of a long-term study that tests the hypothesis that a silvicultural approach called "structural complexity enhancement" (SCE) can accelerate the development of late-successional forest structure and functions. Our objective is to understand the regeneration dynamics following three uneven-aged forestry treatments modified to increase postharvest structural retention: single-tree selection, group selection, and SCE. In terms of regeneration density and diversity, how do light availability, competition, substrate, and herbivory interact with treatment effects? To explore these relationships, manipulations and controls were replicated across 2-hectare treatment units at two Vermont sites. Forest inventory data were collected pre-harvest and over multiple time lags up to 13 years postharvest. We used mixed effects models with repeated measures to evaluate the effect of treatment on seedling and sapling density and diversity (Shannon-Weiner H').

The treatments were all successful in recruiting a sapling class with a significantly higher mean than the control. However, due to high spatial variability, prolific beech sprouting dominates some patches in the understory of all the treatments. Multivariate analyses suggest that while treatment had a dominant effect, other factors were influential in driving regeneration responses. These results indicate variants of uneven-aged systems that retain or enhance stand structural complexity, including old-growth characteristics, generally foster abundant regeneration of important late successional tree species depending on site conditions.

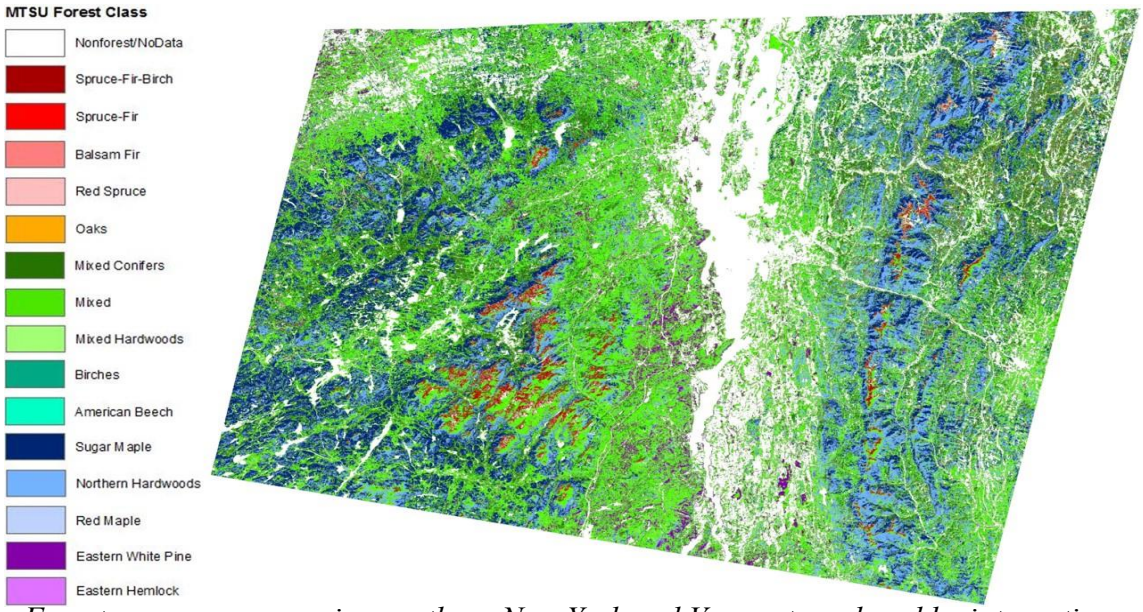
ENHANCED FOREST COVER MAPPING USING SPECTRAL UNMIXING AND OBJECT-BASED CLASSIFICATION OF MULTI-TEMPORAL LANDSAT IMAGERY

David Gudex-Cross[(1)], Jennifer Pontius[(1,2)], and Alison Adams[(1)]

[(1)] UVM Rubenstein School of Environment and Natural Resources,
[(2)]USFS Northern Research Station
djgudexcross@gmail.com , Jennifer.pontius@uvm.edu , aadams@uvm.edu

ABSTRACT

Spatially-explicit tree species distribution maps are increasingly valuable to forest managers and researchers, particularly in light of the effects of climate change and invasive pests on forest resources. Advanced remote sensing techniques, such as spectral unmixing and object-based image analysis (OBIA), offer novel approaches to mapping species distributions by providing information on proportional species composition and classifying on a stand versus pixel level. This is particularly useful in the Northeast where species composition is often highly heterogeneous. Using multi-temporal Landsat imagery, we employed spectral unmixing to quantify percent basal area for ten regionally-common tree species/genera. The percent basal area maps, along with ancillary environmental data, were then used in an OBIA workflow to produce a thematic forest classification across northern New York and Vermont.



Forest cover map spanning northern New York and Vermont produced by integrating spectral unmixing of multi-temporal Landsat imagery and a rule-based, OBIA

We compared the results of our integrated unmixing-OBIA thematic map to other large-scale forest mapping efforts, including the National Land Cover Database (NLCD), National Forest Type Map (NFTM), and LANDFIRE. Independent validation with 50 forest inventory plots across Vermont indicated that our method was 38% accurate (84% fuzzed) at the species-type level, versus 28% (80% fuzzed) for LANDFIRE, and 18% (70% fuzzed) for the NFTM. Since species-type level comparisons were not possible with NLCD, the other three classifications were fuzzed to NLCD categories. Coarse type accuracy was highest for our integrated product (74%), followed by LANDFIRE (66%), the NFTM (62%), and NLCD (56%). These results demonstrate that our integrated unmixing-OBIA method offers higher accuracy and increased specificity in forest cover mapping compared to existing datasets.

EVALUATING THE IMPACTS OF SOUTHERN PINE BEETLE ON PITCH PINE FOREST DYNAMICS IN A NEWLY INVADED REGION

Molly Heuss[(1)], Anthony D'Amato[(1)], Kevin Dodds[(2)]

[(1)]University of Vermont, Burlington, Vermont, USA, 05401, mheuss@uvm.edu , awdamato@uvm.edu
[(2)]USDA Forest Service, Durham, New Hampshire, USA, 03824, kdodds@fs.fed.us

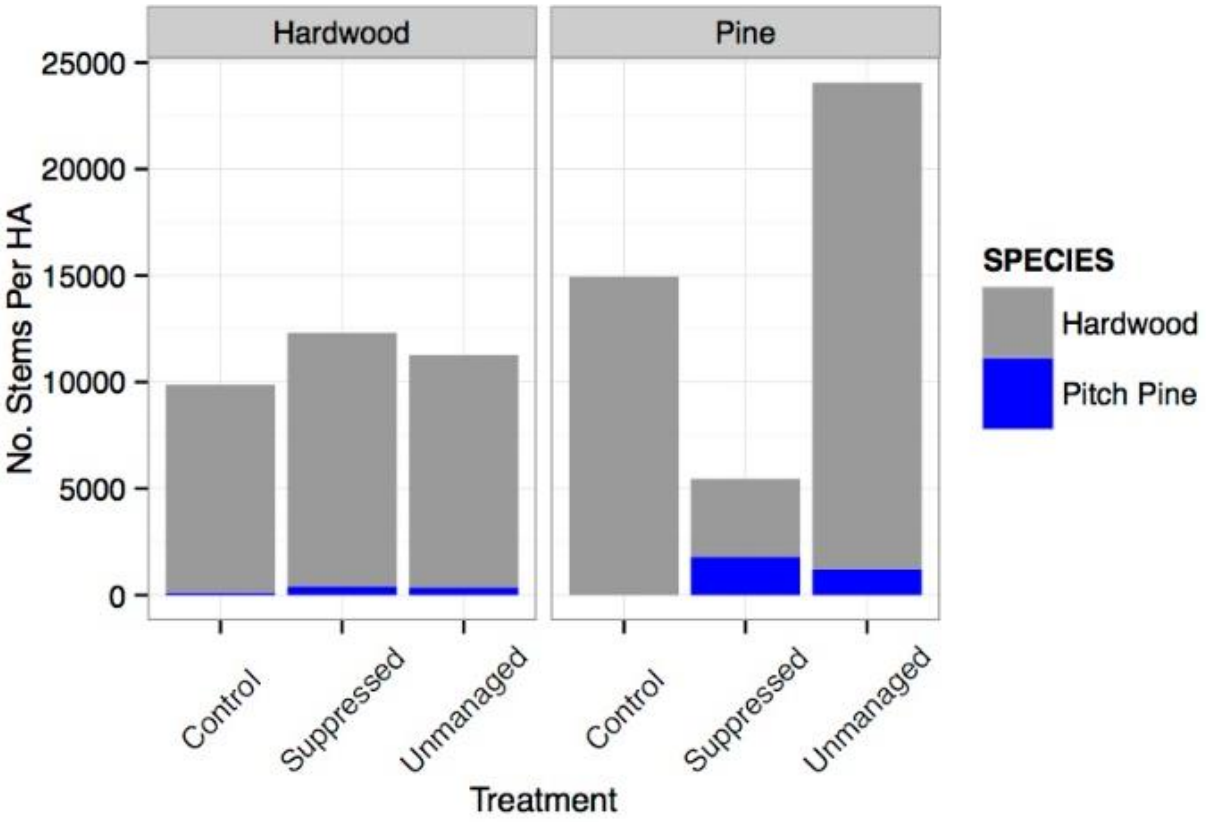
ABSTRACT

Southern pine beetle (SPB), a native insect that has historically affected pine ecosystems in the southeastern U.S., has recently expanded northward causing extensive tree mortality in pitch pine (*Pinus rigida*) and pitch pine-oak forests of eastern Long Island, NY. Given the historic lack of SPB within these ecosystems, little is known regarding its potential impacts on forest structure and function. This study examined the immediate effects of SPB-induced tree mortality and suppression management on the structure and composition of pitch pine and pitch pine-oak stands (n=26) to inform management recommendations and projections of future forest conditions.

Overstory pine importance values in unmanaged stands declined by 64% following SPB, from an average of 50% to 18%. Relative density of pitch pine seedlings was higher in infested stands (μ=7% vs. μ=0.5% in uninfested stands, P = 0.02). Although relative density of pitch pine saplings did not vary significantly, unmanaged pine-dominated stands contained higher densities. Pitch pine comprised <6% of seedlings and saplings, demonstrating a lack of available post-SPB pine regeneration. Collectively, our results indicate SPB could functionally eliminate pitch pine from similar stands in the absence of silvicultural or disturbance-mediated regeneration events, leading to increased hardwood species dominance.

KEY FINDINGS

- Pitch pine dominance declined by 64% in unmanaged stands
- Relative importance of pitch pine seedlings was higher in infested stands
- Pitch pine comprised <6% of post-SPB regeneration



Standardized pitch pine seedling densities (blue; μ=746 stems ha^{-1}) by treatment and cover type were significantly lower than hardwood (grey; μ= 12333 stems ha^{-1}) seedling densities (P< 0.0001). Pitch pine densities were not significantly influenced by cover type or treatment or combined effects.

IMPACTS OF WOODY BIOMASS DEMAND ON TIMBER MARKETS IN NEW ENGLAND AND NEW YORK

Ted Howard[(1)] and Iuliia Drach

[(1)] Corresponding author: *University of New Hampshire, Durham, NH 03825 USA*
ted.howard@unh.edu

ABSTRACT

Due to the region's abundant forest resources and extensive wood harvesting and processing infrastructure, there is interest in New England and New York in using woody biomass as a source of renewable energy. To analyze the impacts of changes in woody biomass demand for energy production on traditional timber markets, we analyzed a reference case and multiple demand and policy scenarios using a modified Sub-Regional Timber Supply model (NE-SRTS). Three scenarios without residuals harvesting restrictions were 1) a steady increase in woody biomass demand, 2) a rapid buildout of planned woody biomass generation facilities, and 3) the eligibility of all hydropower for renewable energy certificates (RECs). These scenarios were re-analyzed assuming a policy prohibition on the use of logging residuals. For the reference case and six scenarios, the responses of inventory, removals and price of four traditional wood product classes (hardwood pulpwood, hardwood sawtimber, softwood pulpwood and softwood sawtimber) were modeled over a projection period of 50 years. Results show that changes in woody biomass demand would affect the hardwood and softwood pulpwood markets, resulting in price and removals increases compared to the reference case scenario in which the current levels of wood biomass demand are assumed to remain constant. The sawtimber markets were not influenced by these scenarios, suggesting that sawtimber inventory, removals and prices are largely independent of woody biomass markets. Similar results were obtained when all scenarios were re-examined via parametric changes in demand and supply elasticities favorable and unfavorable to timber removals.

DAYDREAMS AND NIGHTMARES IN THE NORTHERN FOREST: A QUARTER CENTURY OF CHANGE

Lloyd C. Irland[(1)]

President, The Irland Group, 174 Lord Road, Wayne, Maine 04284, USA, lcirland@gmail.com

ABSTRACT

This extended abstract summarizes some major points that arise in assessing the situation in the Northern Forest over the quarter century since two major federally supported reports assessed issues concerning its forests, forest industry, and communities. The experience reminds us of the limitations of our foresight; Daydreams of a stable forest-based industry and hopes for supportive policies were replaced by nightmares of mill closures and dislocation in local communities. Industry and other landholders viewed as permanent fixtures of the landscape vanished almost completely. Despite these nightmares, some major conservation achievements were made.

KEY FINDINGS

- Assessments of the Northern Forest in 1990 and 1994 are reviewed with the advantage of hindsight.
- Adverse developments in the forest economy were foreseen by nobody.
- Conservation achievements in the 4-state region varied according to local political cultures.
- This was the period in which conservation easements became prominent.

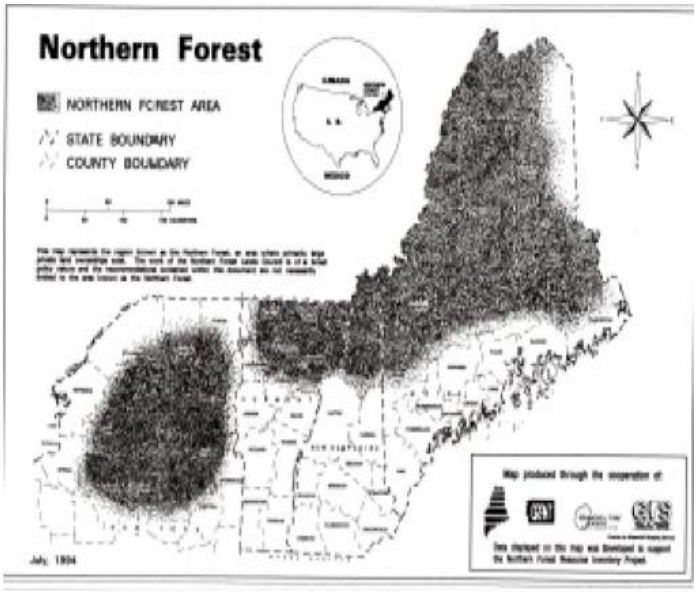
The Northern Forest is a term used by forest activists, policy wonks and some geographers to describe the forested regions of upstate New York, Vermont, New Hampshire and Maine. This is a region of scattered population, glaciated hills and valleys, many lakes and rivers, and several substantial mountain ranges (Irland, 1999; 2011). In its fall displays of color, the red and yellow maples and birches are studded by dark green pines and spruce. It is virtually the last redoubt of native brook trout populations; in a few coastal Maine streams tiny surviving runs of Atlantic salmon cling to life. This region was accustomed to long-standing private ownership by paper companies, well-established timber families, and Kingdom Owners– descendants of New York wealth from the 1890's, with their private lakes and "Adirondack Camps." The region has an aura of remoteness and wilderness character, regularly burnished by writers and artists since Thoreau's visits in the 1840's and the glowing paintings of Hudson River School artists. Into countless households each year, the mail order catalogs of the LL Bean Company arrive, their covers displaying appealing images of wild solitude. They became the suburbanites' mental picture of the Northwoods. Visitors were

often stunned, then, to drive into the woods and see logging trucks, recent clearcuts, and for sale signs for wildland lots. Many wanted something done about it.

A regionwide outbreak of spruce budworm attacked spruce and fir stands from the early 70's to the mid 80's, leading to widely publicized spray programs and accelerated cutting in Maine where the effects were most serious. Recreationists could readily access the most remote corners of the Northwoods on gravel roads, following the end of log driving on the rivers.

This region was the culture hearth of the nation's lumber, log driving, and paper industries; lobbyists and executives for these industries once carried big sticks in state capitals. By the late 1980's, though, large private holdings were beginning to turn over to new owners, often non-industrial ones. Fears began to spread that the traditional model of timberland ownership would burst wide open leading to widespread shoddy subdividing and development, loss of public access, diminished timber supply, and then loss of jobs as mills could not meet their wood needs. In 1990, and again in 1994, major studies were done on these issues, funded by federal dollars.

By the early 1990s, it was thought that by judicious public policy, something resembling the traditionally stable Northern Forest landscape could be retained, fostering stable employment in rural areas and milltowns, widespread public access to private lands, and desirable wildlife habitat. In 1989, a regionwide study was launched, the Northern Forest Lands Study, to assess these issues with a guiding committee of state officials and stakeholders (USDA Forest Service and Governors' Task Force, 1990).



Source: Northern Forest Lands Council, 1994. This region counted 26 million acres of forest in the late 80s. The acreage of forest had barely changed by 2015. In 2015, the NFL region contained 56% of all the forest land in the four states (USDA Forest Service data). Its boundaries were constructed carefully: to avoid federal lands (as in VT and NH), and to avoid as much as possible any small landholders and farmers, while including most of the largest timberland holdings of the region. Much of the private ownership here has changed hands – some more than once, since 1990. For detailed current data, see Shifley and Moser, (2016).

A followup in 2004 was a more ambitious effort to conduct detailed research and develop policy options (Northern Forest Lands Council, 1994; Northeastern State Foresters Association, 2005).

These projects conducted local public meetings to obtain input and encountered loud protests from local groups, especially in the Adirondacks, who – correctly — saw the reports as efforts to build support for more land protection. They saw this as threats to their economy and autonomy (Porter, Erickson, and Whalley, 2009). One result of this was that both reports, while depicting longterm issues and needs, had to tread gingerly by burning incense to the idols of local stakeholder input before any recommendations were made. In its 2004 Report, the Northern Forest Lands Council offered a saccharine vision of the future forest and the industries and communities depending on it. They recognized that this could not be achieved without improved public policies, for which they offered numerous suggestions. But they assumed a level of stability in markets and industry structure that was not to be.

Rarely has there been a more dynamic period in the region's forest history than the 1990-2015 period. Numerous small wood processing companies (Irland 2004) have been driven out of business by furniture imports from China. From 2000 to 2015, newsprint usage nationally fell by 70%; printing and writing paper consumption by one third. The post 2005 housing crash cut national lumber production by half, and it has since barely recovered. Today, there is no paper being manufactured along Maine's Penobscot River, and lumber manufacturing remains as a pale shadow of what once was. Primary paper mills have virtually vanished from New York, Vermont, and New Hampshire.

Paper mill in Bucksport, Maine, running full steam in better days. It is now being dismantled. Its ownership history: St Regis to Champion to International Paper to Verso to scrap dealer in about 2 decades is not atypical of the northeastern industry. In early summer in the late 1930s, the Penobscot River in the foreground would be covered with pulpwood logs. Photo by author.

In parts of the region, more wood is being burned to generate electricity than to make pulp or paper. Had anyone in 1990 predicted all these events they would have been dismissed as delusional. Domestic market crashes and surges in imports upset the hopes for a stable forest economy with prospering little mill towns stretching from Tug Hill to Eastern Maine.

The 1990 study was prompted by concerns that industry would sell its land to others, who would have less reason to keep it in forest and retain public access customs. This concern proved all too well founded: for a host of reasons, forest industries sold off their holdings almost completely, and many of the mills as well (your present writer was among those who failed to predict this). At one time, with a stroll down "Paper Industry Row", on E. 42d Street in New York, you could talk to the owners of much of the forest of the region, or at least their Wall Street bankers. No longer. Many of the longtime family holdings, such as the Adirondack

"Kingdoms" held by heirs of the Robber Barons since the 1890s, went on the block as well. New owners represented a wide variety of interests, including newly rich billionaires, and investment funds managed for pension funds and institutions (Irland, Hagan, and Lutz, 2011). More than a little of this land found its way into conservation uses via NGO's, public agencies, and conservation easements.

The nightmares of the past quarter century cast doubt on the usefulness of efforts to develop "visions" by negotiation among multi-stakeholder groups. Turning points as dramatic as these cannot be foreseen, and even if they are, few stakeholders welcome bad news. Shared visions may even induce complacency, suggesting that everybody believes nothing will really change. One-time efforts by large study groups contain no provision for keeping track to see if assumptions underlying visions are changing. Finally, struggling for agreement on visions may take time better spent on more concrete matters. It could be easier to agree on some of those than on grand overarching visions. Some leaders seem to believe in a therapeutic effect of discussing larger issues and long-term visions, apparently in the hope that divisive issues will more readily yield to agreement once the big picture is agreed upon. Experience suggests that this assumption is often off the mark.

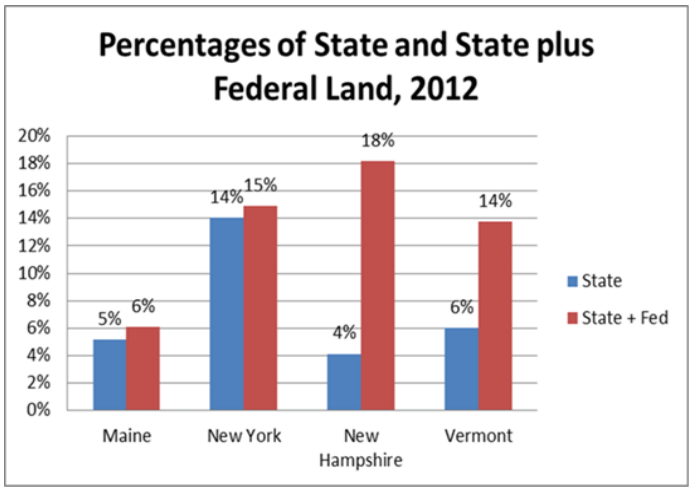
From some perspectives, progress has been made: counting fee ownership and conservation easements, 19% of Maine is now in conservation ownership. Important gaps in the Adirondack Park have been filled in. In many areas, however, the resource "took a haircut" in this process as smaller tracts and outholdings were sold off. Often the buyers were exploitive "liquidators" who stripped the timber and sold the land as "leisure lots" in sizes that would elude local land use controls (if there were any at all). Today, many who loved to hate the paper companies wistfully admit that they wish we could go back to those times. Fortunately, the housing crash has cut deeply into demand for such lots, but signs of gentrification on large "view lots" are emerging once again, especially near ski areas. The old rustic "ski chalet", often self-built, is being replaced by virtual mansions, with 2 car garages and mowed lawns. Development on view lots is eroding the sense of remoteness that once characterized much of this region, with implications for public access and wildlife habitat that are only beginning to be recognized.

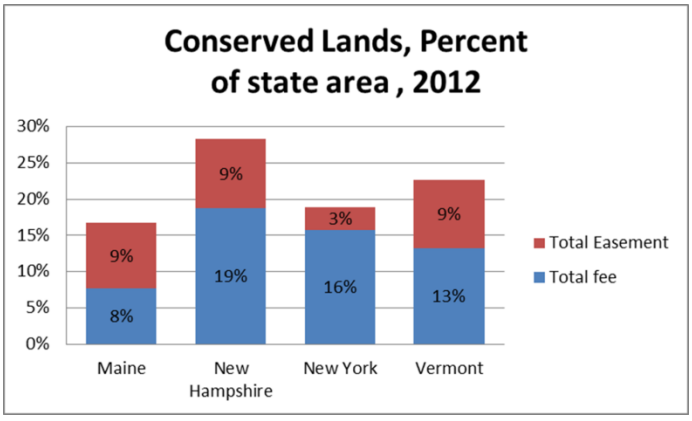
Political cultures regarding public land ownership and regulation vary from state to state across this region, despite its apparent ecological and economic similarities. Substate institutions have arisen in New York (Adirondack Park Authority), New Hampshire (unincorporated portions of Coos county), and Maine (Land Use Planning Commission for 10 million acres lacking any local government). A major influence has been concentrations of wealth and population in the Boston-New York coastal strip. The Northern Forest is the recreational and second home backdrop for these regions, and most of the conservation accomplishment has been lobbied from those urban areas. So the region has a distinct north-south political divide. Broadly speaking, advocates of the National Forests on Vermont and New Hampshire have allowed the 2 states to pass much of the cost and bureaucracy of administering dispersed forest recreation to federal taxpayers. In New York and Maine, by contrast, there is very little federal conservation land, while New York's constitutional Forever Wild in the Adirondacks represents a huge state-managed stretch of wild land.

Both Maine and New York are not favorable to federal ownership, except where federal dollars will pick up costly coastal property (e.g. Acadia NP; Rachel Carson NWR; Fire Island National Seashore on Long Island … but these are not in the Northern Forest). One lesson has been that creating federal land units has been far easier than administering them. Drawing lines on maps cannot make the divisions among various publics go away. Since 1990, changes in fee ownership in the Northern Forest have not been substantial, amounting to only about 800,000 acres leaving private ownership over the quarter century.

Most of the conservation achievement has been via conservation easements, which represent the removal of development rights from land remaining in private hands. Note that in Maine, the September 2016 donation creating the Katahdin Woods and Waters National Monument increased federal ownership by 87,000 acres, an immediate increase of 49%.

A full picture of conservation includes lands covered by easements. In Maine, more land is under easements than owned in fee. New York, with its large Blue line ownerships in the Catskill s and the Adirondacks, is at the other end of the spectrum, relying far less on easements.





These are proportions of total land area owned in fee by states and by the states plus federal agencies. Accurate data on county and municipal lands are elusive. These figures refer to fee simple ownership only. Conservation easements, especially in Maine, augment these figures substantially.

The past quarter century has seen a remarkable degree of "outsourcing" of conservation funding, project negotiation and ongoing management, and financing. Much of the formerly public business of conservation has been delegated to a wide range of local, statewide, and national NGO's specializing in such work. Public funding support and cooperation was usually involved. This enabled the deployment of nongovernmental arbiters well positioned to serve as negotiators and to bring specialized skills and people power to understaffed and overloaded public agencies. It is hard to think of a major conservation accomplishment of this period that did not rely heavily on outsourcing. This has come to be seen as the normal way of doing business, when it in fact is a recent innovation.

The entire region has been accustomed to urban and suburban elites picking and choosing locations for National Parks and other major conservation units, perhaps to a degree unmatched elsewhere in the country. This has yielded major conservation successes: the Adirondack Park, Acadia NP, the White Mountain National Forest, and Baxter State Park. Yet it exacerbates the north-south political divides noted above.

In Maine, since about 2010 an organized program of blowback against the programs favored by Northern Forest Lands advocates has been under way. A Republican governor and legislative allies have been blocking Maine's premier land conservation program, attempting to roll back other conservation policies, and trying to pull the teeth from Maine's Land Use Regulation Commission (newly renamed the Land Use Planning Commission and asked to work with more county

input). This revolt may be narrowly based on a few discontented small businesses in rural areas, but it has had an impact. Leaders of the blowback have not, it seems, paid any political price for their actions. Conservation and environmental groups seem slow to realize the implications.

In 2016, the entomologists are telling us that the spruce budworm is coming back – and its ultimate spread and impacts are unpredictable (Maine Forest Service, 2016). This brings a further dark cloud to the horizon for private forest owners.

The Northern Forest's history of land use change, the underlying forces, and the effectiveness – or lack thereof—of state and federal forest policies offer many important topics for study by geographers, land use experts, foresters, and others (Wallach, 1980). The literature of the field seems sparse in attention to this unusual region; perhaps the Boston meeting of the American Association of Geographers in 2017 will stimulate more interest.

A number of questions emerge from this quick tour of the Northern Forest policy landscape over the past 25 years:

- Is public support for conservation much lower than we'd like to think?
- Have our conservation priorities really been in the right places?
- Is "recreation" alone a sound justification for "conservation" in the wildlands?
- What is really the future of commercial forest management in this region?
- Why have we learned so little about effective policy?

Lloyd C. Irland, a forestry consultant in Maine, former forestry school instructor, and public official in Maine state government, contributed land use analysis to the 1990 Northern Forest Lands study and is author of many papers on forest resources as well as 2 books on the northeast's forests. *The title of this article does homage to Daydreams and Nightmares, a 1971 book by my colleague W. R. Burch Jr, who was one of the earliest to apply sociological insights to forest resource and natural resource problems.*

Acknowledgement: This article originally appeared in the AAG Newsletter of the Association of American Geographers. It has been slightly expanded for this Proceedings. It is available at http://news.aag.org/2016/09/daydreams-and-nightmares-in-the-northern-forest-a-quarter-century-of-change/

REFERENCES

Burch, W. R. Jr. 1971. Daydreams and Nightmares: a sociological essay on the American Environment.New York: Harper and Row.

Foster, David R. et al. 2010. Wildlands & Woodlands: A Vision for the New England Landscape.Petersham: Harvard Forest. May. http://www.wildlandsandwoodlands.org/

Irland, Lloyd C. The Northeast's Changing Forest. Harvard Forest, Petersham, MA (dist. By Harvard Univ. Press). 1999.

Irland, L. C., J. Hagan, and J. Lutz. 2011. Large timberland transactions in the Northern Forest 1980 – 2006. Yale Global Institute for Sustainable Forestry. Private Forests Working Paper No. 11. http://gisf.yale.edu/publications-presentations/gisf-research-reports

Irland, Lloyd C. 2004. Maine's forest industry: from one era to another. In: R. E. Barringer (ed.) Changing Maine. Gardiner, Maine: Tilbury House, pp. 362-387.

Irland, Lloyd C. 2011. "New England Forests: Two Centuries of a Changing Landscape"In, B. Harrison and R. Judd, eds. New England: A Landscape History. Cambridge: MIT Press. Pp. 53-70.

Maine Forest Service 2016. Spruce Budworm Internet Hub: http://www.maine.gov/dacf/mfs/forest_health/insects/spruce_budworm_2014.htm

Northern Forest Lands Council. 1994. Finding common ground: Conserving the Northern Forest. Recommendations of the Northern Forest Lands Council. Concord, NH.

Northeastern State Foresters Association.2005. Northern Forest Lands Council 10th Anniversary Forum. Concord. Northeastern State Foresters Association. www.nefainfo.org/uploads/2/7/4/5/27453461/nflcfr_final…

Porter, W. F., J. D. Erickson, and R. S. Whalley. 2009. The Great Experiment in Conservation: Voices from the Adirondack Park. Syracuse: Syracuse University Press.

USDA Forest Service and Governors' Task Force. 1990. Northern Forest Lands Study. USDA Forest Service, Rutland, VT.

Shifley, S. R. and W, K. Moser, eds. 2016. Future forests of the northern United States. Gen Tech Rep NRS-151. Newtown Square, USDA Forest Service Northern Research station, 388 pp.

Wallach, Bret. 1980. "Logging in Maine's Empty Quarter" Annals of the Association Geographers, vol. 70 (4):542-552.

SILICA ACCUMULATION IN DECIDUOUS TREES: COULD IT BE A SUBSTITUTE FOR LIGNIN?

Roxane Jaffray[(1)(2)], Benoît Côté[(1)(2)]

[(1)] Department of Natural Resource Sciences, McGill University,21,111 Lakeshore Road, Sainte-Anne-de-Bellevue, Quebec H9X 3V9, Canada; roxane.jaffray@mail.mcgill.ca ; benoit.cote@mcgill.ca
[(2)]Centre d'Étude de la Forêt, Université du Québec à Montréal, Montreal, Quebec H3C 3P8, Canada.

ABSTRACT

Silicates are ubiquitous in natural systems. The accumulation of silicon (Si) by plants has been studied in various agricultural crops with findings that Si deprived plants are often structurally weaker and more susceptible to abnormalities of growth, development and reproduction. Limited studies have focused on trees in temperate forests. Si could be 10-20 times energetically cheaper than lignin while having a similar effect on the cell wall. This could confer a competitive advantage for Si-accumulating plants.

In this study, we hypothesized that trees that are high in leaf Si have lower leaf lignin and higher tannin concentrations. The International Diversity Experiment Network with Trees (IDENT) plantation situated in Sainte-Anne-de-Bellevue, Quebec, was used to examine over a four-month growing period how foliar Si concentration varies among nine deciduous tree species and in relation to leaf chemical properties such as lignin, cellulose and tannins. Trees were sampled from monoculture plots in each of the four blocks. Leaf Si concentration was determined through oven-induced digestion and colorimetric analysis, while lignin was by ADF and ADL procedures. Condensed tannins were extracted with 50% methanol, followed by a proanthocyanidins assay with acid butanol. Si concentrations were negatively correlated with lignin (r=0.7) and condensed tannins (r=0.5) (species average used). Takashi and colleagues (1990) characterized three discerning groups for plant species, these were identified as Si accumulators (Si content higher than 1.0%), Si-excluders (Si content lower than 0.5%) and Si-intermediates (Si content in-between 1.0% and 0.5%).

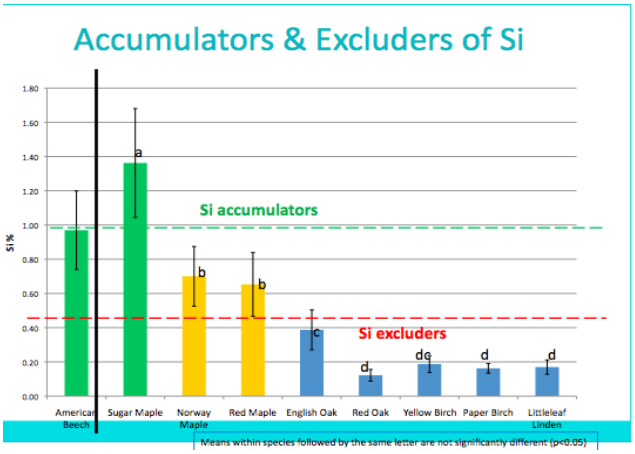
Our results suggest that American beech and sugar maple are active Si accumulators, Norway maple and red maple are Si- intermediates (also referred to as passive accumulators), and English oak, red oak, yellow birch, paper birch and littleleaf linden are Si-excluders. Both American beech and sugar maple had low lignin concentrations with high silica contents. The highest condensed tannins results were expressed in American beech and yellow birch, whereas red maple had the lowest condensed tannin leaf concentration. Unlike the other species, beech had relatively high condensed tannin paired with high Si

KEY FINDINGS

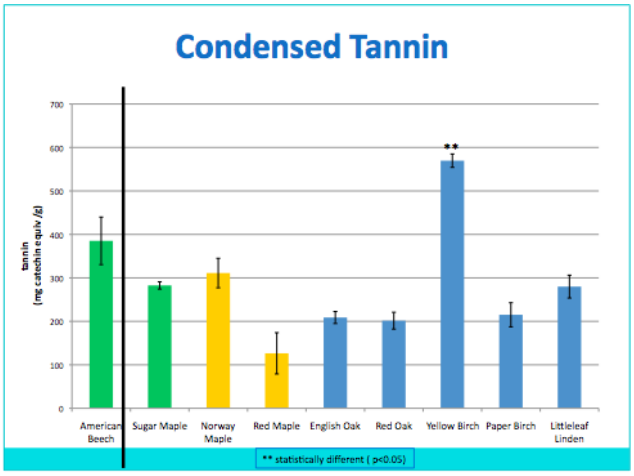
- American beech and sugar maple are Si accumulators.
- Results for beech, a shade tolerant species, support the hypothesis that leaves with a high Si content are lower in lignin and higher in tannin concentrations.

concentrations, suggesting that the Si and phenolic pathways in leaves could be interdependent in that species.

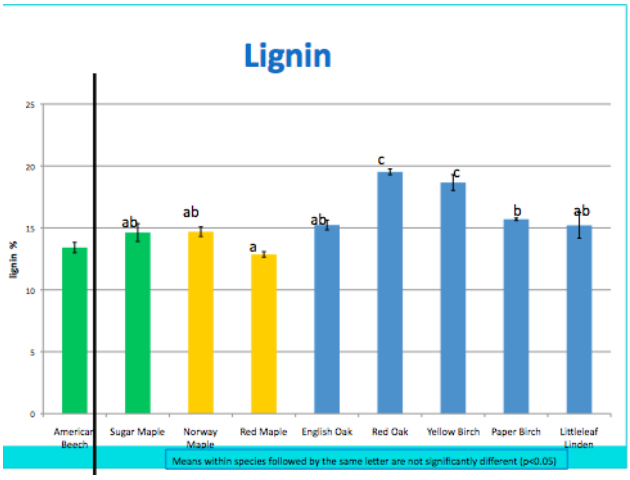
All Si-excluders demonstrated a low Si to cellulose ratio. Red oak and yellow birch species had high lignin, and low Si concentrations thus supporting the hypothesis of an inverse relationship. Red oak had a high lignin concentration along with a high lignin to cellulose ratio and low tannins concentration. Further research is necessary to determine the underlying mechanisms and functions of Si in the cellulose, tannin and lignin metabolism of hardwoods.



Top: *Species Si concentration (%): Si accumulators' American beech and sugar maple, above or equal to 1%, are in green. Si passive accumulators Norway and red maple are in yellow. Si-excluders English and, red oak, yellow and paper birch, littleleaf linden, below 0.5%, are in blue. The vertical bar indicates that American beech was sampled at a different site from the other species, not included in the statistics. Means within species followed by the same letter are not significantly different (p<0.05).*



Middle: *Condensed tannin concentrations (mg catechin equiv. g -1). Green = Si accumulators, yellow= Si passive accumulators, blue= Si-excluders. Means within species followed by the same letter are not significantly different (p<0.05).*



Bottom: *Lignin concentrations (%).Green = Si accumulators, yellow= Si passive accumulators, blue= Si-excluders. Means within species followed by the same letter are not significantly different (p<0.05).*

ASSESSING VULNERABILITY OF FOREST ECOSYSTEMS IN NEW ENGLAND AND NORTHERN NEW YORK

Maria Janowiak[(1)], Tony D'Amato[(2)], Chris Swanston[(3)], Leslie Brandt[(4)], Patricia Butler[(5)], Stephen Handler[(6)], Danielle Shannon[(7)]

[(1)]Northern Institute of Applied Climate Science, USDA Forest Service, 410 MacInnes Dr., Houghton MI 49931, USA, mjanowiak02@fs.fed.us
[(2)]Rubenstein School of Environment and Natural Resources University of Vermont 204E Aiken Center Burlington, VT 05405, USA, awdamato@uvm.edu
[(3)]Northern Institute of Applied Climate Science, Northern Research Station, USDA Forest Service, 410 MacInnes Dr., Houghton MI 49931, USA, cswanston@fs.fed.us
[(4)]Northern Institute of Applied Climate Science, USDA Forest Service, 1992 Folwell Ave., St. Paul, MN 55108, USA, lbrandt@fs.fed.us
[(5)]Northern Institute of Applied Climate Science, School of Forest Resources and Environmental Science, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931, USA, prbutler@mtu.edu
[(6)]Northern Institute of Applied Climate Science, USDA Forest Service, 410 MacInnes Dr., Houghton, MI 49931, USA, sdhandler@fs.fed.us
[(7)]Northern Institute of Applied Climate Science, School of Forest Resources and Environmental Science, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931, USA, dshannon@mtu.edu

ABSTRACT

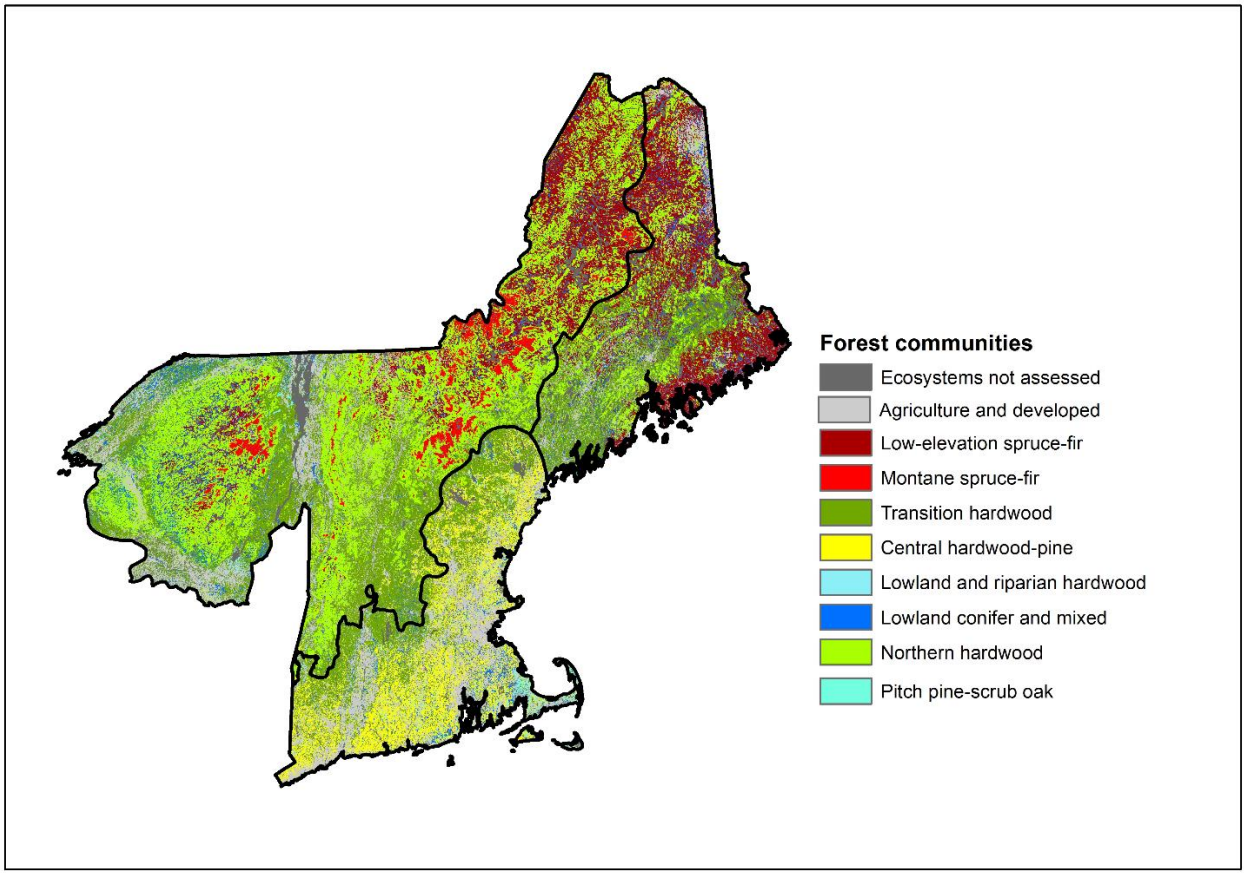
There is a growing interest among forest managers for integrating information about anticipated climate impacts and risks into management planning and activities. Vulnerability assessments can serve a critical role in this integration by providing credible, high-quality information at the scales most relevant to management. We used the latest scientific research to develop a vulnerability assessment for forest ecosystems in New England and northern New York in order to inform management planning and actions.

We used the ecosystem vulnerability assessment approach (described by Brandt et al. 2016) to assess the vulnerability of the region's forests across a range of possible future climates (Janowiak et al. in review). New projections of forest change from three forest impacts models—the Climate Change Tree Atlas, Linkages, and

KEY FINDINGS

- The area's forests will increasingly be affected by a changing climate.
- Understanding potential impacts is a critical for sustaining forests.
- Some tree species and forests communities are more vulnerable.

LANDIS PRO—were combined with a review of recent literature to understand the potential for forest change during the next century under different climate scenarios. An "expert panel" of research scientists and forest practitioners then worked together to consider this information, as well as their personal experience and expertise on local ecosystems, to assess the vulnerability of eight forest communities present across the region.



Current distribution of forest communities include in the vulnerability assessment. Forest communities are aggregated from vegetation macrogroups provided in the Terrestrial Habitat Map for the Northeast US and Atlantic Canada (available via the Conservation Gateway at https://goo.gl/8JYzQt).

KEY FINDINGS: CLIMATE

- **The climate has changed.** Over the past century, the region has warmed by about 2.4° F on average. Winter temperatures have increased the most, and average winter temperatures are now 3.5 °F warmer than in the early 1900s. Warmer temperatures have increased the growing season by more than 10 days. Precipitation has increased across the region, with the greatest increases occurring in October and November. Across the region, much of the additional precipitation is coming in heavy rain events.

- **Temperatures will increase.** All global climate models project that temperatures will increase in the region. Model projections suggest an increase in temperature over the next century by 2 to 8 °F in all seasons. Growing seasons will continue to lengthen due to warmer temperatures. Evidence suggests that winter temperatures will increase in the area, even under low emissions, leading to changes in snow patterns and freeze-thaw cycles.
- **Precipitation will change.** Precipitation is projected to increase in winter. There are greater differences in model projections for the growing season, but evidence seems to indicate there may be a decrease in summer precipitation in at least some parts of the region. Even if the total amount of annual precipitation increases, some evidence suggests it may fall during heavier rain events interspersed among relatively drier periods.

KEY FINDINGS: FORESTS

- **Soil moisture patterns will change, and vegetation may experience moisture stress.** Seasonal changes in precipitation are expected across the assessment area, and the trend toward more frequent heavy rainfall events is expected to continue. Warmer winters may lead to earlier snowmelt in the spring, and longer growing seasons combined with warmer temperatures may lead to more frequent moisture stress during the growing season.
- **Northern species will face increasing stress from climate change.** Each species will have a unique response to climate change. Several northern and boreal species, such as black spruce, red spruce, tamarack, and paper birch, are expected to have reduced habitat and productivity by the end of the 21st century. The degree to which tree species decline will vary greatly by location and site conditions, with greater risk at southern locations and low elevations.
- **Southern species will be favored by climate change.** Many tree species currently at the central or northern extent of their range are projected to have increases in habitat and productivity through the next century. Some species present south of the assessment area are projected to increase, but fragmentation may limit natural migration of these species.
- **Species and forests that can tolerate disturbance are at lower risk.** Climate change is expected to increase some types of disturbance over the next century, including extreme rain events, floods, and pest outbreaks. Tree species and forest types that are better able tolerate these disturbances may be favored. At the same time, it still may be possible for disturbance-adapted systems to undergo too much disruption.
- **Healthy and diverse forests generally have greater resilience to change.** Studies have consistently shown that more-diverse ecosystems are more resilient to changing conditions, while those with lower diversity have fewer options to respond to change. There are many aspects to forest diversity—including species, structural, and genetic diversity—and each of these can generally help reduce risk and increase the ability of forests to adapt to climate change.

VULNERABILITY OF FOREST COMMUNITIES

Climate change will not affect all forest species, communities, and parts of the landscape in the same way. Montane spruce-fir, low-elevation spruce-fir, and lowland mixed conifer forests were determined to be the most vulnerable because a number of important northern and boreal species are expected to decline. Central hardwoods, transition hardwoods, and pitch-pine scrub oak forests were perceived as having lower vulnerability to projected changes in climate because these forests contain species are generally expected to be favored under climate change. These vulnerability determinations generally apply across the landscape, but they will be influenced by local conditions, forest management, and land use. Projected changes in climate and their associated impacts and vulnerabilities will have important implications for ecologically and economically valuable forest types, forest-dependent wildlife and plants, recreation, and long-term natural resource planning.

LITERATURE CITED

Brandt, L.A., P.R. Butler, S.D. Handler, M.K. Janowiak, P.D. Shannon, C.W. Swanston. 2016. Integrating science and management to assess forest ecosystem vulnerability to climate change. http://dx.doi.org/10.5849/jof.15-147

Janowiak, M.K., A.W. D'Amato, C.W. Swanston, L.R. Iverson, F. Thompson III, W. Dijak, S. Matthews, M. Peters, A. Prasad, J.S. Fraser, L.A. Brandt, P.R. Butler, S.D. Handler, P.D. Shannon, D. Burbank, J. Campbell, C. Cogbill, M.J. Duveneck, M. Emery, N. Fisichelli, J. Foster, J. Hushaw, L. Kenefic, A. Mahaffey, T.L. Morelli, N. Reo, P. Schaberg, K.R. Simmons, A. Weiskittel, S. Wilmot, D. Hollinger, E. Lane, L. Rustad, P. Templer. in review. New England and New York Forest Ecosystem Vulnerability Assessment and Synthesis: a report from the New England Climate Change Response Framework. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

IMPACTS OF BEST MANAGEMENT PRACTICES ON LOGGING COSTS AND PRODUCTIVITY

Matthew C. Kelly[(1)], Rene' H. Germain and Steven Bick

[(1)] Corresponding author: Michigan Technological University, School of Forest Resources and Environmental Science, 178 Noblet Horner Hall, Houghton, Michigan, USA mkelly@mtu.edu

ABSTRACT

Best management practices (BMPs) effectively mitigate erosion and sedimentation during and immediately following harvest operations. The responsibility of implementing BMPs typically falls on loggers, with implications for higher harvesting costs and, possibly, reduced logging productivity. Two methods were used to assess impacts of BMPs on logging operations in the Northeast U.S. First, a case study was conducted using shift-level production and activity data and machine rate calculations to assess impacts of BMP implementation for eight harvest operations, ranging from single-operator hand-felling systems to fully mechanized whole-tree and cut-to-length systems. Second, a survey was conducted in which loggers were asked to estimate the number days required to complete a hypothetical timber harvest with and without a set of prescribed BMPs and to indicate their minimum acceptable contract rates for each. The combined results revealed a range of costs from $0/ac to $62/ac and decreases in productivity between 0% and 20%.

MANAGING MULTI-AGED MIXEDWOOD STANDS: PERSPECTIVES FROM THE PENOBSCOT EXPERIMENTAL FOREST IN MAINE, USA

Laura S. Kenefic[(1)] and Robert S. Seymour[(2)]

[(1)]*U.S. Forest Service, Northern Research Station, Bradley, ME,* USA *lkenefic@fs.fed.us*

[(2)]*University of Maine, School of Forest Resources, Orono, ME, USA* *rseymour@maine.edu*

ABSTRACT

For more than 60 years, researchers at the Penobscot Experimental Forest in Maine, USA have been studying multi-aged silviculture in mixedwood (softwood and hardwood) stands. Forest composition is dominated by *Tsuga canadensis, Abies balsamea,* and *Picea rubens* in mixture with other softwoods (*Pinus strobus* and *Thuja occidentalis*) and hardwoods (*Acer*, *Betula, Quercus*, and *Populus* species). Management is complicated by intermingling of species with different silvical properties and different vulnerabilities to forcing agents. Findings reveal expected shifts in composition: proportions of shade-tolerant species increased in treatments with light removals and small (i.e. single-tree) canopy openings, while proportions of intermediate and shade-intolerant species increased in treatments with larger canopy openings (i.e., gaps). In addition, we observed differences in treatment outcomes related to selective herbivory (e.g., browsing of *T. occidentalis* and *P. rubens*) and species-specific regeneration substrate requirements and growth potentials that affect relative abundance and recruitment rates. Managing submerchantable classes to direct stand composition and development has emerged as an important part of multi-aged management in this forest type. Overall we found that advantages of mixedwoods are not fully realized in lowland *Picea-Abies* stands if heavy partial cutting increases hardwoods at the expense of desired softwoods. Recommendations based on observations of classical (selection) and ecological (Acadian Femelschlag) uneven-aged silvicultural systems include managing regeneration with a shelterwood sequence, gaps and reserve trees, or early stand tending.

TIMBER HARVESTING THROUGH SPACE AND TIME: UNDERSTANDING AND MANAGING FORESTS ACROSS THE RURAL-SUBURBAN INTERFACE

David B. Kittredge[(1) (2) (4)], Jonathan R. Thompson[(1)], Luca Morreale[(1)], Anne G. Short Gianotti[(3)], Lucy Hutyra[(3)]

[(1)] Harvard Forest. 324 North Main Street, Petersham, MA USA 01366
[(2)] Department of Environmental Conservation. University of Massachusetts. Amherst, MA USA
[(3)] Department of Earth and Environment. Boston University. Boston, MA USA
dbkitt@gmail.com , jthomps@fas.harvard.edu , lmorreale@fas.harvard.edu , agshort@bu.edu , lrhutyra@bu.edu

ABSTRACT

Many small private forest owners perceive non-consumptive or appreciative benefits from their woods to be incompatible with harvesting, and hence decide to not manage. In addition to these owner attitudes, other related landscape context factors may influence the likelihood of harvest, including general population density, road density, size of properties (and hence available volume of timber), population or development pressure (e.g., real estate values, new building permits), and extent to which the landscape is forested. These factors and others can also differentially influence the likelihood of harvest on public lands in this larger forested matrix and across this rural - suburban interface. In addition, the situation is likely a dynamic one, and properties that yielded timber in the past may no longer do so today. This study examines the diversity of social and biophysical factors that combine to influence the probability of harvest under dynamic rural-to-suburban conditions in Massachusetts. Timber harvest regulatory data over 30 years on private and public ownerships throughout 328 towns in the state of Massachusetts provide an indication of the likelihood of harvest over time. The results of where harvest occurs and does not occur in the suburban-rural interface influence the availability of timber to support local economies, and the ecological structure and composition of remaining forest (e.g., carbon sequestration) in the future.

SILVICULTURAL EFFECTS ON COMPOSITION AND STRUCTURE OF NORTHERN CONIFERS IN THE ACADIAN FOREST REGION: THE COMPARTMENT MANAGEMENT STUDY IN MAINE, USA

Rachel A. Knapp[(1)], Laura S. Kenefic[(2)], Aaron Weiskittel[(3)]

[(1)]University of Maine, School of Forest Resources, Nutting Hall, Orono, ME, USA 04469, rachel.a.knapp@maine.edu

[(2)]U.S. Forest Service, Penobscot Experimental Forest, 686 Government Road, Bradley, ME USA 04411, lkenefic@fs.fed.us

[(3)]University of Maine, School of Forest Resources, Nutting Hall, Orono, ME, USA 04469, aaron.weiskittel@maine.edu

ABSTRACT

The Penobscot Experimental Forest (PEF), located in Bradley, Maine, is one of 80 experimental forests and ranges maintained by the U.S. Forest Service nationwide. This experimental forest was established in 1950 and has been the home to dozens of studies over the years. The forest is within the Acadian Forest and is dominated by red spruce, balsam fir and eastern hemlock along with red maple and paper birch.

The Compartment Management Study (CMS, a spruce-fir silviculture study) was established in 1952. Eight treatment types plus a control are managed, in replicate, across approximately 400 acres. The treatments include uneven-aged silviculture (5, 10, and 20 year selection cycles), even-aged silviculture (2 and 3 stage shelterwood), and exploitive cutting practices (fixed diameter limit, modified diameter limit and commercial clearcut).

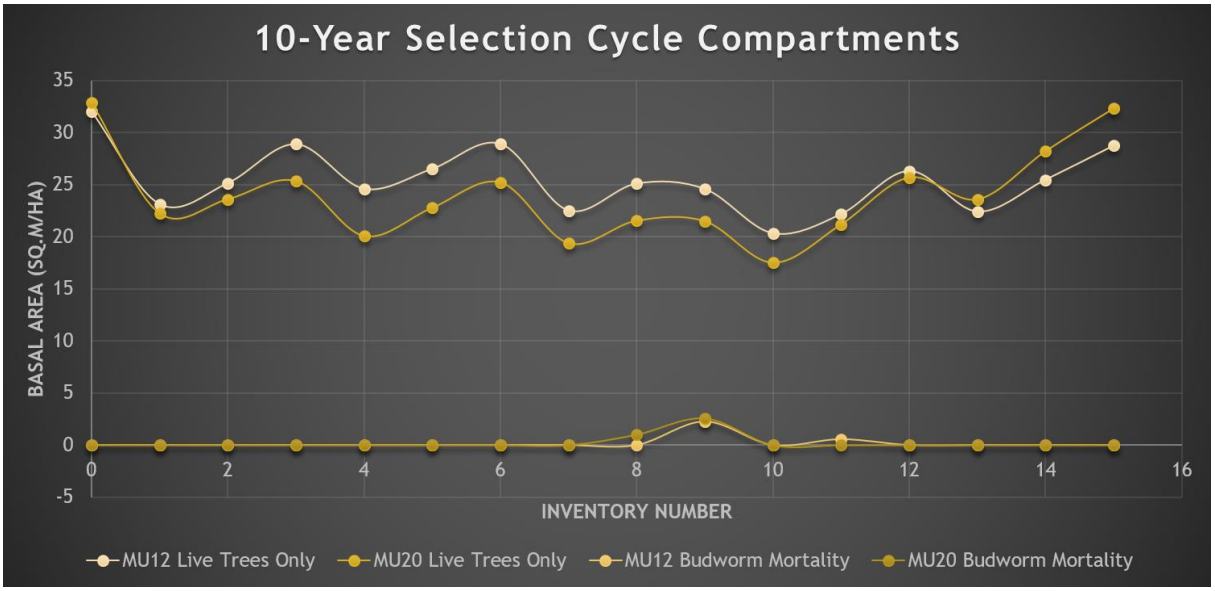
In partnership with the Forest Service's Research Data Archive, data and metadata from the CMS has been published online. These data tables include diameter at breast height and/or diameter class for sapling and overstory trees; spatial distribution, total height, base to live crown height and crown radii for select overstory trees; and regeneration inventories.

KEY FINDINGS

- Primary study objective is to quantify response to silvicultural treatment.
- The study has been ongoing since 1952.
- Data is available online:

  http://www.fs.usda.gov/rds/archive/Product/RDS-2012-0008-2

Published data were reviewed and a snapshot of results showing spruce budworm mortality were considered.



This graph shows change in basal area over time from the first inventory to the last for the two 10 year selection cycle compartments, Compartment 12 and 20. The top two lines represent live trees only. The bottom two lines represent trees that dies during a spruce budworm outbreak. The stands were harvested every 10 years. The growth and harvest pattern was changed due to the budworm outbreak.

INVESTIGATING THE SURPRISING, RECENT GROWTH INCREASE OF RED SPRUCE TREES ACROSS THE REGION

Alexandra M. Kosiba[(1)], Paul G. Schaberg[(2)], Shelly Rayback[(3)] Gary Hawley[(1)]

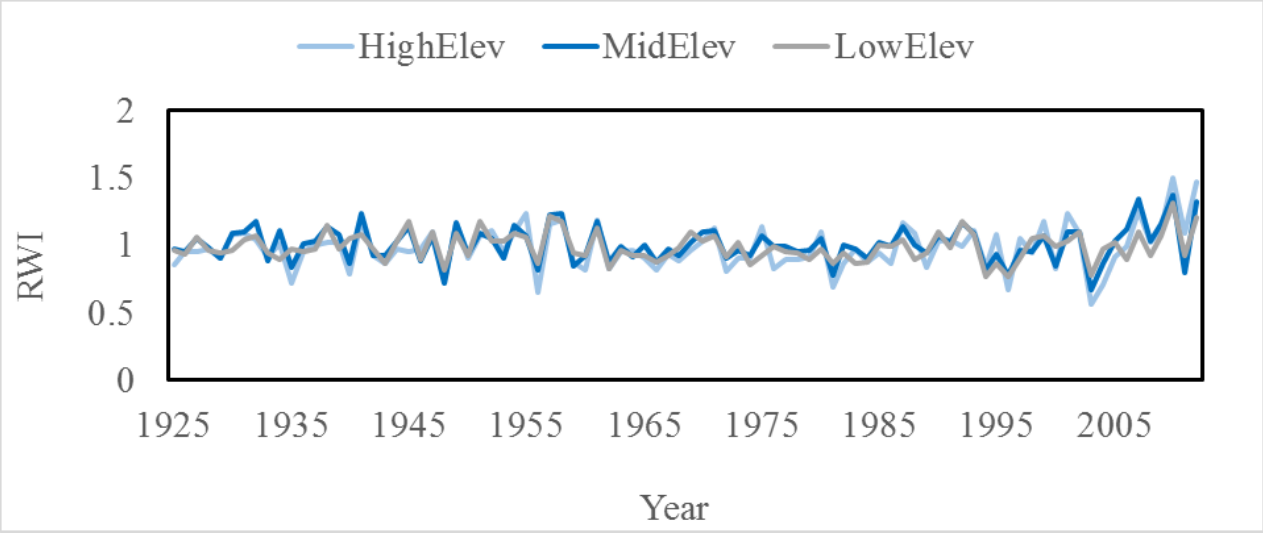
[(1)]The University of Vermont, Rubenstein School of Environment and Natural Resources, Burlington, VT 05405, USA, akosiba@uvm.edu , ghawley@uvm.edu
[(2)]Forest Service, U.S. Department of Agriculture, Northern Research Station, Burlington, VT 05405, USA, pschaberg@fs.fed.us
[(3)]The University of Vermont, Department of Geography, Burlington, VT 05405, USA, srayback@uvm.edu

ABSTRACT

Recent investigations have uncovered an unanticipated trend: red spruce (*Picea rubens* Sarg.) trees in the northeastern US are undergoing a marked surge in growth. This discovery stands in contrast to the declines in growth and vigor for red spruce that were documented in the second half of the 20th century and attributed to acid deposition-induced calcium depletion. Further, predictions of potential range shifts due to climate change depict red spruce habitat constricting from low elevations and latitudes. Considering these conflicting findings, we asked: what factors are most likely stimulating growth increases for red spruce? Here we use a uniquely large and both spatially- and temporally-explicit tree ring dataset to assess changes in red spruce growth over time. We compare patterns in growth to local weather data, atmospheric deposition rates, and other environmental and forest-stand metrics, including soil nutrient status and buffering capacity. These results allow us to model areas in the region where we predict similar growth increases for red spruce. Through this study, we suggest that this temperate conifer may be uniquely poised to benefit from a lengthened functional growing season, increased annual temperatures, particularly in winter, and decreased atmospheric pollution levels that proved problematic in the past.

KEY FINDINGS

- Red spruce trees have shown unprecedented growth rates in recent years.
- This trend is not dependent on elevation.
- Reduced pollution and climate warming may play a part in this change.
- We found positive relationships with winter, annual temperature and rain pH.



Detrended and standardized ring width index values for red spruce trees at >55 plots (n trees: 688) and displayed by elevation category (low <650 m, high >950 m). Recent growth increases are evident for all elevations.

ENVIRONMENTAL VARIABLES ASSOCIATED WITH INVASIVE GLOSSY BUCKTHORN (FRANGULA ALNUS MILL.) AND INDIRECT CONTROL STRATEGIES FOR FOREST MANAGERS

Joshua Kozikowski and Ted Howard

University of New Hampshire, College of Life Sciences and Agriculture, Rudman Hall, 46 College Road, Durham, New Hampshire 03824 USA ted.howard@unh.edu

ABSTRACT

Glossy buckthorn (*Frangula alnus* Mill.) is one of the most prominent nonnative invasive woody plant species affecting New England forests. We investigated the environmental variables associated with glossy buckthorn density and its effect on native tree regeneration in forested ecosystems by sampling in three locations across New Hampshire, USA. The objective was to gain an understanding of where glossy buckthorn grows to better manage the species indirectly through silviculture and management. Glossy buckthorn was found at its highest densities in disturbed white pine (*Pinus strobus* L.) forests that were historically old fields, with a thin organic layer and low herbaceous cover, on drained loam and clay soils. Scatter plots and generalized linear models showed that organic layer thickness, dominant overstory species, percent herbaceous cover, drainage class, soil type, historical land use, and evidence of harvest were the most influential variables in predicting density of buckthorn. Relationships between buckthorn and environmental variables were much stronger in softwood stands than hardwood stands. Softwood stands were primarily white pine and some eastern hemlock (*Tsuga canadensis*). We found evidence of direct competition between glossy buckthorn and native regeneration although there was no effect on the average shade tolerance of native species regenerating with glossy buckthorn present. With this information we designed a proto-type prescription risk tree for forest managers faced with risk and uncertainty when planning a harvest in the presence of glossy buckthorn.

CAPACITY FOR RECOVERY, INFLEUNCE OF COMMERICAL THINNING & RESISTANCE TO DEFOLIATION IN SPRUCE-FIR FORESTS

CJ Langley [(1)], Mike Day [(1)], Brian Roth [(2)]

[(1)] University of Maine, Orono ME, USA, cjlangley6@gmail.com; daym@maine.edu
[(2)] Cooperative Forestry Research Unit, Orono ME, USA, brian.roth@maine.edu

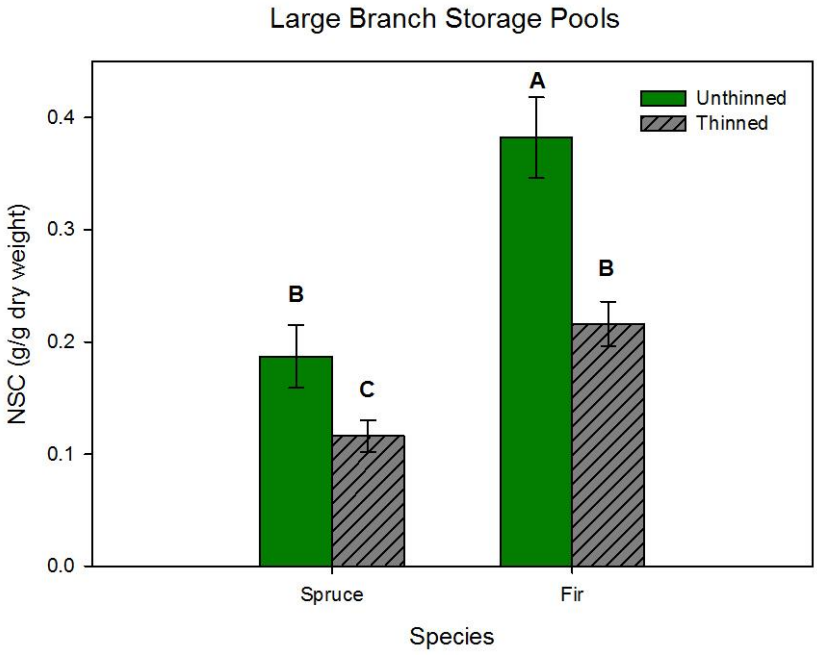
ABSTRACT

To manage the stress caused by large scale, repeat defoliation caused by the eastern spruce budworm (*Choristoneura fumiferana*), trees must balance nonstructural carbohydrate (NSC) reserves between tolerance and defensive strategies. A tree's ability to tolerate and recover following an outbreak is linked to the pool of NSC available to stimulate growth of latent buds, while secondary defensive compounds, such as soluble phenolics, measured as tannic acid equivalence (TAE), provide resistance against defoliation. Although commercial thinning treatments have the potential to increase NSC pools, and defoliation has the potential to induce the production of secondary defensive compounds, studies conducted during past outbreaks have reported conflicting results.

This study evaluates the eco-physiological responses of red spruce (*Picea rubens*) and balsam fir (*Abies balsamea)* to stand-level thinning and artificial defoliation treatments across three experimental locations throughout the state of Maine. In contrast to carbohydrate allocation theory, the results of this study suggest that stand level thinning treatments lower the NSC concentrations available to both species which could leave trees within thinned stands vulnerable during an outbreak. The production of secondary defensive compounds was not induced in response to the artificial defoliation treatments. Contrary to expectations, balsam fir was found to maintain higher concentrations of both NSC and TAE than red spruce, which should mean that balsam fir is better adapted to tolerate and resist defoliation caused by the spruce budworm. However, this is not the trend that has been reported historically when defoliation and mortality of the species are compared.

KEY FINDINGS

- Storage allocation patterns are consistent with species life history strategy.
- Balsam fir maintains higher concentrations of NSC & TAE.
- Thinning lowers NSC.
- Defoliation treatment did not trigger the production of 2° defensive compounds.



Effect of thinning on NSC concentrations in large branch storage pools. Thinning treatments lower the concentration of NSC available within large branch storage pools for both red spruce and balsam fir. Species data has been pooled, $p < 0.01$, bars represent standard errors, N= 118.

Thinned stands represent a considerable investment on the part of forest managers and should be a top priority for insecticide applications to protect foliage and/or (pre)salvage harvest operations. However, this study was unable to decipher the impact thinning intensity or timing of treatments have on concentrations of NSC and vulnerability. To best predict risk and determine the proper course of action, forest managers must work with researchers and outreach specialists across the ECANUSA region to monitor populations early using pheromone traps, L2 density surveys, and satellite imagery to monitor moth migrations.

ECONOMIC IMPACTS OF EARLY INTERVENTION TO SUPPRESS A SPRUCE BUDWORM OUTBREAK IN NORTHERN NEW BRUNSWICK

Eric Ye Liu [(1)], Van A. Lantz[(1)], David A. MacLean[(1)]

[(1)]*Forestry and Environmental Management,*
University of New Brunswick, Fredericton, NB, Canada
macleand@unb.ca

ABSTRACT

Spruce budworm (*Choristoneura fumiferana* Clem.) (SBW) causes large scale spruce-fir mortality and major regional economic losses. Under uncontrolled moderate and severe SBW outbreaks, total output in the New Brunswick (NB) economy over the 2012-2041 period would decline in present-value terms by CDN $3.3 billion and $4.7 billion, respectively (Chang et al. 2012). Past management against SBW outbreaks has been reactive, using large-scale pesticide aerial spraying programs to keep trees alive rather than alter SBW population dynamics. Recently, the concept of an early intervention strategy to reduce the upcoming SBW outbreak has been proposed and is being tested in NB. An early intervention strategy would involve intensive monitoring and early detection of low but rising SBW populations, small area target-specific pesticide application, and tools and techniques to disrupt SBW moth mating and migration. By spraying biological insecticide on SBW 'hotspots', an early intervention strategy would control low but rising SBW populations to prevent hotspots from developing into epicenters that trigger a regional outbreak. We are studying the costs and benefits of an early intervention strategy, relative to reactive SBW management. Alternative SBW hotpot temporal and spatial dynamics, resulting spruce-fir defoliation levels, and an early intervention treatment plan are being simulated for all 2.8 million hectares of Crown forest in NB. We will use the Spruce Budworm Decision Support System (SBW DSS) and a dynamic Computable General Equilibrium (CGE) model to estimate the economic impacts, costs, and benefits of conducting an early intervention strategy on regional economies.

SPRUCE BUDWORM IS BACK. CAN WE INTERVENE EARLY TO REDUCE OUTBREAKS?

David A. MacLean[(1)]

[(1)]*Forestry and Environmental Management,*
University of New Brunswick, Fredericton, NB, E3B 5A3 Canada
macleand@unb.ca

ABSTRACT

Evidence is mounting that eastern North America is on the cusp of another major spruce budworm (*Choristoneura fumiferana* Clem.) outbreak, with defoliation in Québec increasing from 6.3 million ha in 2015. Spruce budworm is the most damaging insect in North America, and detailed economic analyses have indicated that potential losses of a moderate to severe outbreak in the eastern Canada/US would be $41-59 billion. We are testing an early intervention strategy to suppress spruce budworm population growth and prevent damage in a 4-year, $18 million research program that began in New Brunswick in 2014. The project includes over 30 researchers and collaborators from Natural Resources Canada, five universities, New Brunswick Department of Natural Resources, and forestry companies. An early intervention strategy would involve intensive monitoring and early detection, small area target-specific pesticide application, and tools and techniques to disrupt mating and migration. Trials in 2014, 2015, and 2016 in northern NB and Quebec demonstrated successful Mimic, Btk, and pheromone trials population reduction in identified 'hot spots'. We are also conducting intensive budworm population ecology and natural enemies research, testing inoculation of planted seedlings with endophytic fungi that have insect suppressing qualities, use of satellite and airborne hyperspectral sensing of low-level defoliation, radar detection of moth flights, and a decision support system for optimizing forest protection operations. The research includes an active public communications program. Treatments to date have been successful in reducing spruce budworm populations over 80,000 hectares, and continued intensive monitoring is being used to plan programs for 2017. Although the research is continuing, three years of results indicate that an early intervention strategy against spruce budworm may be feasible.

ANALYSIS OF THE FACTORS CONTROLLING FOREST PRODUCTIVITY IN NORTHEASTERN U.S FOR IMPROVED APPLICATION OF REMOTE SENSING

Conor Madison, Scott V. Ollinger

University of New Hampshire College of Life Sciences and Agriculture, Rudman Hall, 46 College Road, Durham, New Hampshire 03824 USA conormadison9@gmail.com

ABSTRACT

Biomass production in forests is a key process in the global carbon cycle. Spatially, patterns of forest growth vary as a function of climate, soils and species composition (e.g. Smith et al. 2002), however our understanding is far from complete and can be complicated by trends that are poorly understood. Given these uncertainties, studies designed to simultaneously examine factors controlling spatial patterns in productivity will help lead to a greater understanding of the carbon cycle across broad terrestrial ecosystems. An investigation of the main factors controlling productivity in different forests types will also provide data for extrapolation using remote sensing and ecosystem models. The proposed research is designed to address these knowledge gaps by measuring wood growth, photosynthetic rates, and foliar chemistry (C13 and N15) of two well-studied northeastern U.S. research sites. Results will be used to improve spatial estimates of forest growth using high spectral resolution remote sensing and a widely used ecosystem model.

TESTING EXPERIMENTAL SILVICULTURAL TREATMENTS TO MITIGATE FOLIAR PATHOGENS AFFECTING EASTERN WHITE PINE IN THE NORTHEASTERN US AND CANADA

Cameron McIntire[(1)], Heidi Asbjornsen[(1)], Isabel Munck[(2)]

[(1)]University of New Hampshire Dept. of Natural Resources and the Environment, 114 James Hall 56 College Road, Durham, NH 03824, USA), Cameron.d.mcintire@gmail.com

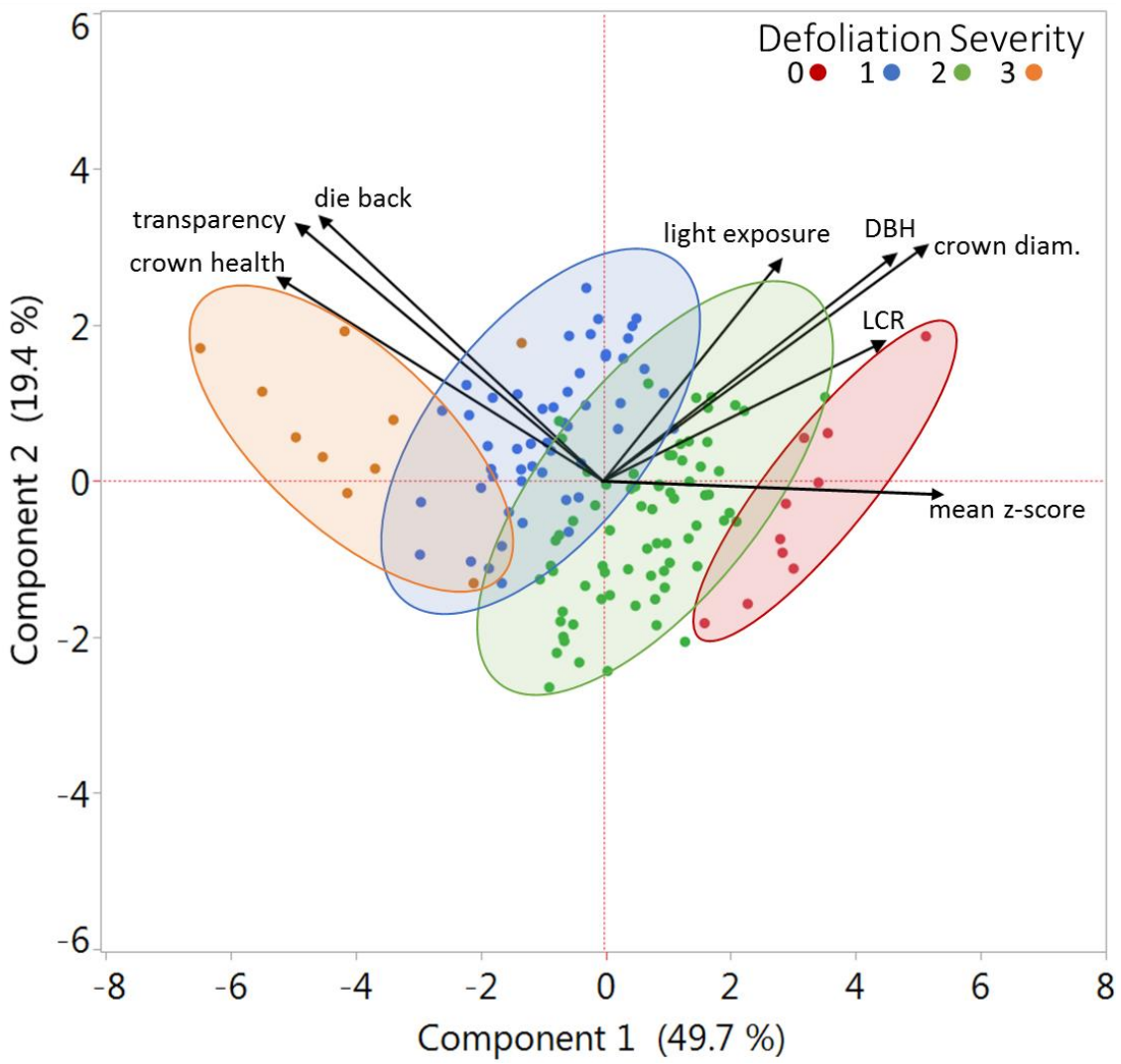
[(2)]US Forest Service: State and Private Forestry ,USDA Forest Service - Northern Research Station, 271 Mast Road, Durham, NH 03824, USA, imunck@fs.fed.us

ABSTRACT

White Pine Needle Damage (WPND) is a complex of foliar pathogens that have established and become a chronic disease impacting forests in the northeastern US and Canada. Chronic annual summer defoliations caused by WPND have garnered widespread concern from regional foresters and landowners. With the long term ecological and economic impacts in mind, it is critical to develop management recommendations for moderating the effects of WPND on our white pine dominated forests. A primary step in recommending any sort of silvicultural treatment to the public at large is to first test and verify an appropriate prescription. The work presented here will evaluate the effectiveness of mechanical tree removal (thinning) as a means to both enhance *P. strobus* growth and mitigate disease severity of WPND. During the summer of 2015 two replicated experimental blocks were established in Hillsborough and West Ossipee, NH. In the subsequent winter of 2015-16 one-acre treatment plots consisting of low density thinning (60 BA/ac), high density thinning (100 BA/ac) plots were cut. Growth and forest health metrics of diameter at breast height, live crown ratio, crown diameter, crown light exposure, crown transparency, crown die-back, and WPND severity will be monitored in the experimental plots over the ensuing years. Inventory data from the pre-treatment year indicated a strong correlation between WPND severity and decreased live crown ratios, crown diameter, as well as increased levels of crown die-back and transparency. The results of this study will be used to inform regional forest management in the context of WPND outbreaks.

KEY FINDINGS

- Trees impacted by WPND exhibit thin crowns and reduced wood growth.
- z-scores can be used to quantify tree health .
- Thinning treatments appear to reduce pressure of WPND in the first year.



Principle component analysis of the pre-treatment data shown in two dimensions. Most of the variation is explained by component axis-1, and the discrete clustering of health classes is primarily occurring along that axis; where healthier crowns are associated with enhanced DBH, LCR, crown diameter, and light exposure. Conversely, high-severity individuals are associated with poor transparency, dieback, and crown health. The calculated mean z-score using the 7 tree metrics shows the vector aligning with the majority of the variation and crown health clustering of the dataset.

ASSESSING THE EFFICACY OF TWO SPECIES OF SILVER FLY, *LEUCOPIS ARGENTICOLLIS* AND *LEUCOPIS PINIPERDA*, AS BIOLOGICAL CONTROL AGENTS OF HEMLOCK WOOLLY ADELGID, *ADELGES TSUGAE*, IN THE EASTERN US

Kyle Motley, Nathan Havill, Darrell Ross, Albert Mayfield and Kimberly Wallin

University of Vermont, 85 Carrigan Dr. Burlington, VT 05489 USA kyle.motley@uvm.edu

ABSTRACT

The hemlock woolly adelgid (*Adelges tsugae*, Annand; HWA) is a non-native, invasive insect threatening the survival and sustainability of eastern and Carolina hemlocks (*Tsuga canadensis* and *T. caroliniana*). HWA is established in over half of the total range of eastern hemlock and the entire range of Carolina hemlock. Its continued spread and associated hemlock mortality make research into biological control of HWA crucial. There are no known parasites of adelgids, therefore biological control research has been focused on predators. Field surveys of predators associated with HWA in the Pacific Northwest identified a strong correlation between HWA abundance with *Laricobius nigrinus* and two species of silver fly, *Leucopis argenticollis* and *Leucopis piniperda*. Flies in the genus *Leucopis* are known specialist predators of adelgids and recent studies have shown a strong synchronization between the lifecycles of *Leucopis* spp. and HWA. *Leucopis* spp. are the most successful examples of past biological control for other adelgid species worldwide. The purpose of this study is to evaluate the establishment, life cycle and impact of *Leucopis* spp. on HWA in laboratory and field experiments in the eastern United States to better quantify its potential as a biological control agent.

NORTHERN MIXEDWOOD SITE PRODUCTIVITY 50 YEARS AFTER WHOLE-TREE AND STEM-ONLY HARVESTING, WITH AND WITHOUT PRESCRIBED BURNING

(1) Bethany Muñoz, (1) Laura S. Kenefic, (2)Aaron Weiskittel and (3)Ivan Fernandez

(1)U.S. Forest Service, Northern Research Station,
(2) University of Maine, School of Forest Resources,
lkenefic@fs.fed.us , aaron.weiskittel@maine.edu , ivanjf@maine.edu

ABSTRACT

This study reports the long-term (50-year) outcomes of biomass harvesting and slash disposal (site preparation) treatments in northern conifer (mixedwood: softwood-hardwood) stands. Forest biomass production and utilization have potential to both increase forest carbon stocks and reduce carbon dioxide emissions from combustion of fossil fuels. Whole-tree harvesting (WTH) is commonly used to extract forest biomass for energy and commercial wood products. However, removal of tree tops and branches in WTH has led to concerns about long-term sustainability of production, particularly in conifer forests on low fertility sites. In addition, effects of post-harvest prescribed burning on productivity of intensively managed (clearcut) stands are poorly understood in northern mixedwood stands. To address these research questions, we are using a U.S. Forest Service experiment, established in 1964 on the Penobscot Experimental Forest in Maine, to evaluate the long-term effects of WTH, stem-only harvesting (SOH) with and without prescribed burning (SOHB), and site quality on stand structure, composition, and carbon stock 50 years after treatment. We found that neither treatment nor site conditions had an effect on total live-tree density, mean dominant height, percent hardwood composition, or coarse woody material carbon stock. However, basal area, total aboveground live-tree carbon stock, and total aboveground carbon stock were found to be lowest on SOH treated areas with high O horizon thickness. This suggests that neither WTH nor SOHB reduced northern mixedwood site productivity 50 years after harvest, as reflected by stand structure or composition. Analysis of soil and foliar nutrition (ongoing) will further inform productivity outcomes.

RAPID LANDSCAPE MONITORING USING DRONES

Jarlath O'Neil-Dunne

University of Vermont, Spatial Analysis Lab, 85 Carrigan Dr. Burlington, VT 05489 USA
joneildu@uvm.edu

ABSTRACT

Drones provide an unmatched capability to capture high-temporal, high-spatial resolution imagery of our changing landscape. This presentation will dive into drone technology and show how it is being used to map forested ecosystems.

UVM's Spatial Analysis Laboratory deployed a drone to assist first responders in assessing the Amtrak derailment in Northfield on Oct. 5, 2015.

CLIMATE CHANGE ADAPTATION IN ACTION: LESSONS FROM NORTHERN FOREST ADAPTATION DEMONSTRATION PROJECTS

Todd A Ontl[(1)], Leslie Brandt[(2)], Patria Butler[(3)], Stephen Handler[(4)], Maria Janowiak[(5)], Chris Swanston[(6)]

[(1)] USDA Northern Forests Climate Hub & Northern Institute of Applied Climate Science, USDA Forest Service, 410 MacInnes Dr., Houghton, MI 49931, USA, tontl@fs.fed.us

[(2)] Northern Institute of Applied Climate Science, USDA Forest Service, 1992 Folwell Ave., St. Paul, MN 1491 55108, USA, lbrandt@fs.fed.us

[(3)] Northern Institute of Applied Climate Science, School of Forest Resources and Environmental Science, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931, USA, prbutler@mtu.edu

[(4)] Northern Institute of Applied Climate Science, USDA Forest Service, 410 MacInnes Dr., Houghton, MI 49931, USA, sdhandler@fs.fed.us

[(5)] Northern Institute of Applied Climate Science, USDA Forest Service, 410 MacInnes Dr., Houghton, MI 49931, USA, mjanowiak02@fs.fed.us

[(6)] USDA Northern Forests Climate Hub & Northern Institute of Applied Climate Science, USDA Forest Service, 410 MacInnes Dr., Houghton MI 49931, USA, cswanston@fs.fed.us

ABSTRACT

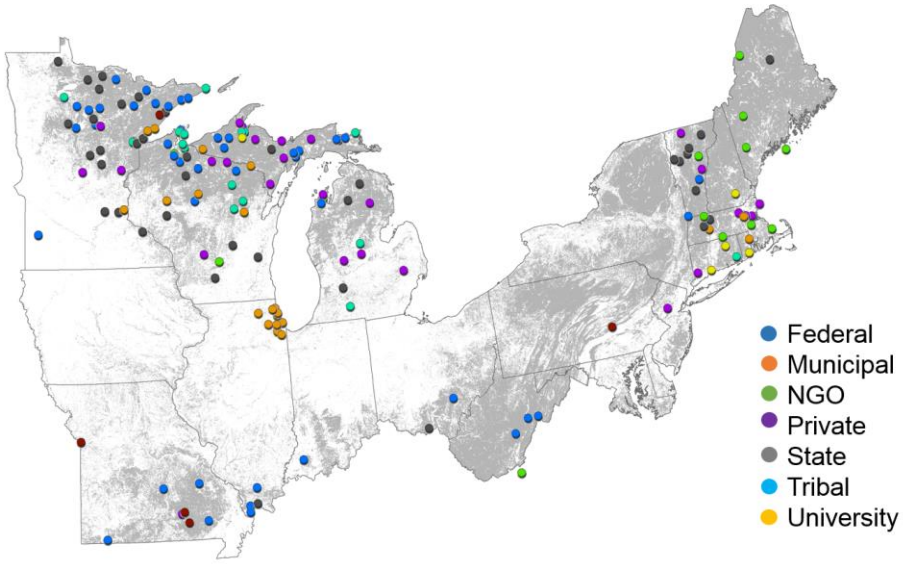
The Northern Institute of Applied Climate Science has built a successful approach that helps land managers pursue climate change adaptation (www.forestadaptation.org). A flexible but rigorous Adaptation Workbook helps translate general climate change expectations to specific risks and opportunities at the scale of management decisions. The Adaptation Workbook is used in conjunction with applicable information on climate change impacts, including NIACS ecosystem vulnerability assessments co-created with diverse groups of managers and researchers. A "menu" of adaptation strategies and approaches helps users generate concrete adaptation actions. More than 185 real-world case studies across the Midwest and Northeast US illustrate how land managers have used the Adaptation Workbook. These

KEY FINDINGS

- Concern of climate impacts and adaptation actions differed between ownership types and regional locations.
- Impacts from forest pests and diseases and soil moisture stress were of greatest concern.
- Managers are employing a diversity of adaptation approaches, utilizing actions to resist impacts, enhance forest resilience, and transition towards systems better adapted to future conditions.

examples cover a wide range of scales, ecosystem types, and ownerships, and show how land managers can prepare for climate change while still meeting land management and conservation goals.

This summary provides an overview of the resources that have been developed through the Framework, including the Adaptation Workbook, and describe adaptation efforts that are underway. Drawing upon lessons learned from the existing network of demonstration projects, we discuss opportunities common across many projects and highlight regional characteristics of adaptation projects that are well-poised to increase the ability to adapt to future conditions



Over 185 forest adaptation demonstration projects have been developed with partners across numerous land ownership types throughout the Midwest and northeastern U.S.

APPROACH:

Planning documents developed using the Adaptation Workbook framework were reviewed from 44 on-the-ground natural resource management projects within the Laurentian Mixed Forest (LMF) and Central Interior Broadleaf Forest (CIBF) ecoregional provinces. Quantitative content analysis was used to identify 1) climate change impacts of concern, and 2) the suite of adaptation actions selected to reduce

vulnerability to those impacts. Multivariate analyses (non-metric multidimensional scaling, PERMANOVA) tested the influence of ownership type and ecoregion on climate impacts and adaptation actions. Comparisons were made between federally-managed lands in the LMF and CIBF to provide insights into regional differences in adaptation among these regions. Additionally, projects on federal- and privately-owned lands within the LMF ecoregion were compared to look for the differences among ownership types. Lastly, preliminary review of adaptation projects located within ecoregions of northeastern U.S. (e.g., Northeastern Mixed Forest and Eastern Broadleaf Forest provinces) was conducted to provide examples of climate impacts and adaptation responses for the northeastern U.S. forests.

KEY FINDINGS:

- Multivariate analyses of the 44 projects representing seven ownership types among the two ecoregional provinces showed both ownership type and region influenced adaptation plans.
- The climate impact of greatest concern was insect pests and fungal pathogens, followed closely by soil moisture stress. Other impacts of high concern included altered precipitation (e.g., changing seasonality of precipitation, and extreme precipitation), increased temperatures (e.g., seasonal increases in temperature, longer growing seasons), and reduced snowpack/ frozen ground impacting winter harvests.
- Regional differences in impact concerns was greatest for altered precipitation, which was higher in the CIBF region (37%) compared to the LMF (16%).
- Within the LMF, ownership differences were apparent for concerns over soil moisture stress, which was lower for private ownership (4%) compared to federal ownership (17%).
- Analysis of adaptation actions showed managers are applying a diversity of approaches to reduce impact vulnerabilities. Actions included increasing resistance, enhancing resilience, and transitioning forests.
- Actions intended to transition forests were highest within the CIBF ecoregion (45%) compared to LMF (28%). Transition actions in CIBF focused largely on restoring species composition and structure by selecting once dominant drought-tolerant species and opening up canopies. Transition actions in LMF focused on encouraging heat- and drought-tolerant tree species typically found to the south.

CASE STUDIES:

- Shorter winter seasons with reduced snowfall are impacting the ability to conduct winter harvests. The Atlas Timberlands project conducted by the Vermont Land Trust/ The Nature Conservancy is addressing this by changing the site's road and drainage infrastructure to allow summer harvest activities.

- Increased extreme rainfall events, warmer temperatures, and insect pests are impacting the integrity of fish habitat within streams in New England. Trout Unlimited is addressing these impacts in the North River watershed on the Massachusetts/ Vermont border through replacing undersized culverts and installing in-stream wood additions to improve habitat, while implementing forest management practices that reduce the effects of the hemlock woolly adelgid on riparian vegetation.
- Higher summer temperatures combined with more variable precipitation results in increased occurrence of soil moisture stress, leading to greater tree stress. Providence Water is addressing these impacts at the Scituate Reservoir by selecting for drought-tolerant species during harvests, while also planting species expected to be batter adapted to higher temperatures and more frequent periods of prolonged moisture stress.

ASSESSING SPATIAL PATTERNS OF THE EFFECTS OF NITROGEN DEPOSITION ON FORESTS USING A GIS MANAGEMENT TOOL FOR CRITICAL LOADS AND EXCEEDANCE

Linda H. Pardo[(1)], Molly Robin-Abbott, Claire B. O'Dea, Jennifer Pontius, Jason A. Coombs

[(1)]*Corresponding author: USDA Forest Service, Northern Research Station, 85 Carrigan Dr. Burlington, VT USA* *lpard@fs.fed.us*

ABSTRACT

Maintaining commercially important tree species, as well as species valued for ecological, social, and cultural reasons, is becoming increasingly challenging in the northeastern U.S. due to the significant threats impacting ecosystem health and sustainability over the long term, in particular climate change and nitrogen (N) deposition. We developed a GIS-based tool, Nitrogen Critical Loads Assessment by Site (N-CLAS), to evaluate the impact of multiple stressors (N deposition and climate change) simultaneously for species of management concern on public and private forest lands. In addition to calculating species-specific critical loads, N-CLAS is designed to take into account the impact of site abiotic factors on the response of trees to N deposition. The abiotic modifying factors include, precipitation, temperature (e.g., January T, July T, May-September T), and soil characteristics. Application of N-CLAS across the northeastern U.S. allows us to evaluate which areas and tree species are most susceptible to impacts from N deposition. We can determine the critical load and exceedance for individual tree species or all the species present. We have incorporated climate change scenarios in order to explore the interaction between climate change and nitrogen deposition. Thus, we are also able to determine the fraction of the region that is susceptible to detrimental impacts of N deposition under projected climate scenarios. Use of this tool provides resource managers with a simple way to incorporate the current state-of-the-science knowledge into their planning and management decisions.

THE COMPLEX RELATIONSHIP BETWEEN CLIMATE AND SUGAR MAPLE HEALTH: CLIMATE CHANGE IMPLICATIONS FOR A KEY NORTHERN HARDWOOD SPECIES

Jennifer Pontius[1,2], Evan Oswald[3], Lesley-Ann Dupigney-Giroux[3], Sandy Wilmot[4], Shelly Rayback[3], Paul Schaberg[2]

[1]UVM Rubenstein School of Environment and Natural Resources, 85 Carrigan Dr. Burlington, VT 05405 USA
Jennifer.pontius@uvm.edu
[2]USFS Northern Research Station,
[3]UVM Department of Geography,
[4]VT Forests Parks and Recreation

ABSTRACT

Sugar maple's important ecological and economic role in northeastern forests has made it one of the best studied species in eastern North America, but many questions remain about the potential drivers of recent sugar maple decline. In order to better understand which climate characteristics influence sugar maple vigor, we compared annual sugar maple crown condition metrics from 25 years of long-term monitoring at 30 North American Maple Project plots (including assessment of canopy dieback, transparency and the percent of trees with high dieback and transparency normalized to one Forest Stress Index (FSI)) to a suite of ecologically relevant climate metrics calculated using downscaled climate data. These relationships were then used to examine spatial and temporal variability in historical climate-induced decline, and use high resolution climate projections to better understand potential impacts of ongoing climate change on sugar maple health.

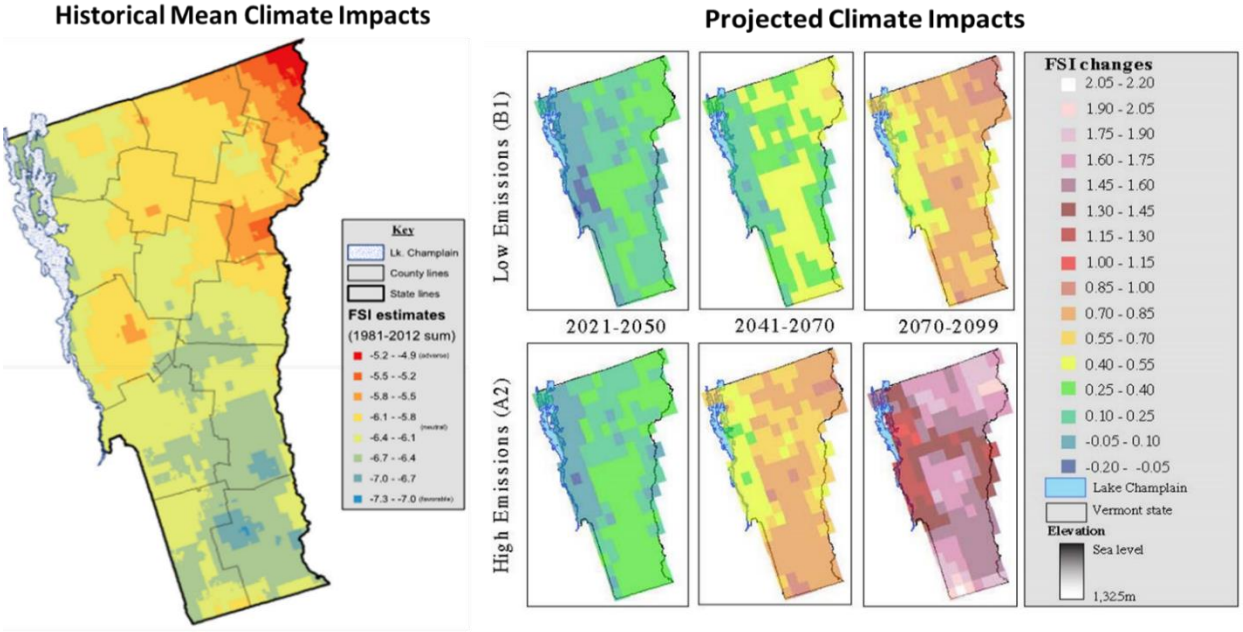
KEY FINDINGS

- Changes in climatic conditions have been detrimental to sugar maple health over the past 25 years.
- Under a low emissions scenario, sugar maple will be in moderate to severe decline 35% of the time by 2050. This increases to 50% under a high emissions scenario.
- Models indicate that climate conditions for sugar maple will deteriorate across the state, but that climate refugia will also exist.
- Management efforts should be targeted where sugar maple is most likely to tolerate changing climate and secondary stress agents can be minimized.

Yearly FSI values were modeled against climate and disturbance metrics in an iterative partition regression model to isolate the impact of climate variables on sugar maple condition. Five climate metrics were identified that were significantly related to sugar maple decline. While three of these were the monthly based metrics commonly used in climate analyses (minimum April, August and October temperatures), two were novel metrics designed to capture extreme climate events (periods of unusual warmth in January and August). These five key climate metrics accounted for ~19% of the variability in historical sugar maple condition. Adding disturbance accounts for another 11%, indicating that climate conditions, though rarely included in sugar maple decline studies, may be of equal importance as more traditionally studied stress agents.

Modeled across the state, results indicate that ongoing changes in climatic conditions have been detrimental to sugar maple health over the study period, and are likely to degrade further over time based on climate projections. However, geographic variability in projected climate-driven decline indicates that, while conditions for sugar maple will deteriorate across the state, climate refugia should also be available to maintain sugar maple in spite of changing climatic conditions.

Considering the predominant role of sugar maple in the northeastern economy and culture, managing this resource into the future as climate changes is of great concern and could pose a considerable challenge. It will become increasingly difficult to manage sugar maple on marginal sites. Instead management efforts should be targeted where sugar maple is most likely to tolerate changing climate and secondary stress agents can be minimized. Adaptive management strategies should be taken to prepare for the loss of sugar maple in high risk locations.



*Modelled across the state, results indicate that ongoing changes in climatic conditions have been detrimental to sugar maple health over the study period **(left)**, and are likely to degrade further over time based on climate projections **(right)**.*

LANDSCAPE SCALE ASSESSMENTS OF FOREST PRODUCTIVITY: METHODS, PATTERNS AND TRENDS

Jennifer Pontius[(1)(2)], Shelly A. Rayback[(3)], Emma Tait[(3)], Jesse Little[(1)], John Kilbride[(3)]

[(1)]UVM Rubenstein School of Environment and Natural Resources,
85 Carrigan Dr. Burlington, VT 05405 USA
Jennifer.pontius@uvm.edu
[(2)]USFS Northern Research Station
[(3)]UVM Department of Geography

ABSTRACT

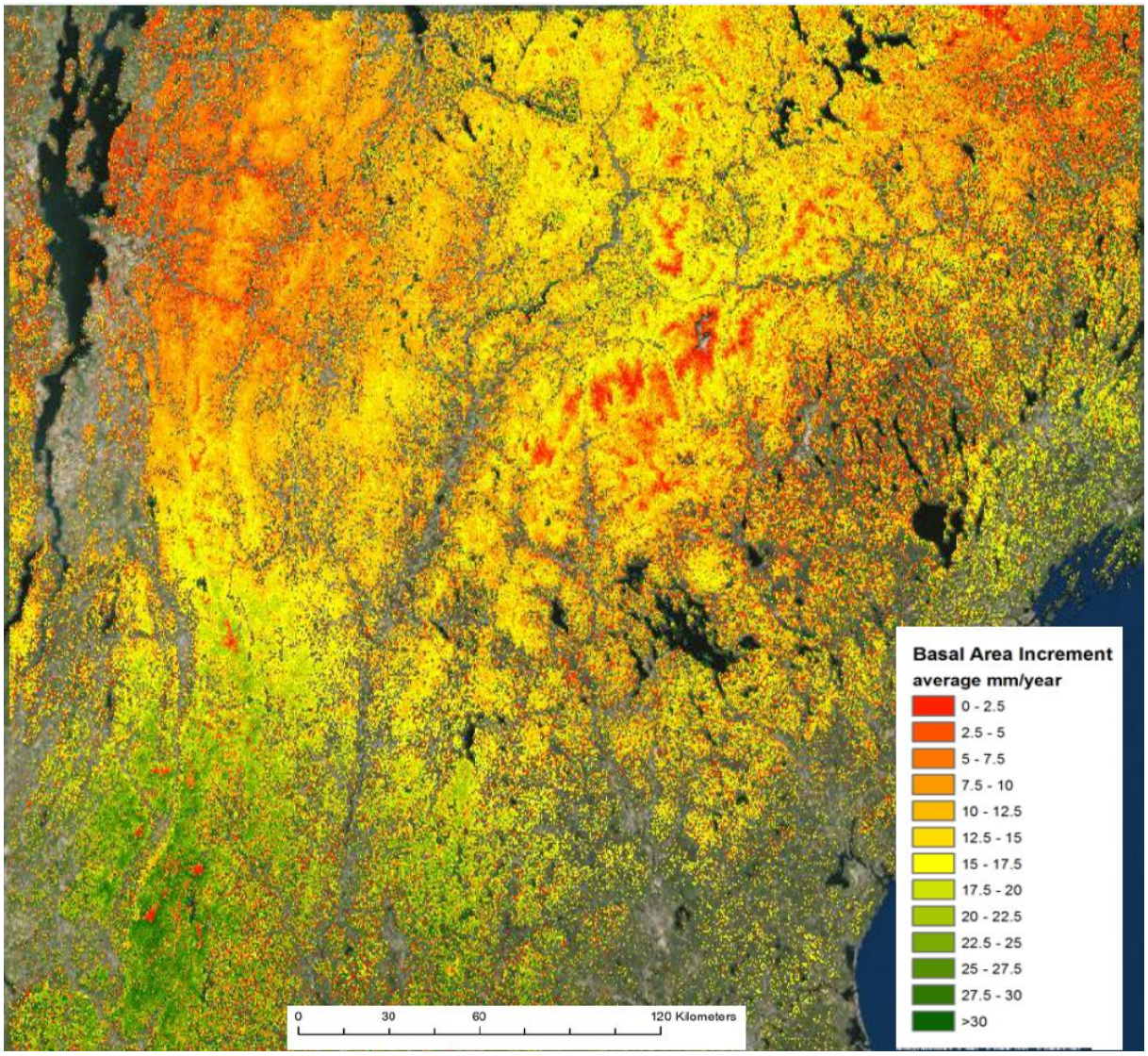
Remote sensing can provide a relatively low-cost approach to large scale assessment of forest productivity to enable investigations into spatial and temporal trends in forest growth. Much of the existing research has focused on homogeneous, single species forests, with limited remote sensing inputs for model calibration or field data to assess accuracy of productivity predictions.

Here we present results of a basal area increment (BAI) productivity model based on remote sensing data products as well as ancillary spatial data layers to capture site, stand, and relative habitat suitability. Calibration and validation based on dendrochronologies from 132 plots located across Vermont and New Hampshire, indicate that modeling forest productivity across a heterogeneous landscape is difficult based on the complexity of spectral characteristics in mixed stands, variability across the landscape and diversity of factors influencing tree growth on a micro-scale. However, species specific models can be built and applied across these landscapes with sufficient accuracy to inform spatial and temporal patterns in forest productivity. Initial application of these

KEY FINDINGS

- Forest productivity can be accurately mapped using remote sensing products if calibrated by species.
- Remotely sensed assessments of productivity shows distinct spatial patterns across the landscape primarily driven by species composition.
- Some species show increasing growth trends (American beech and red spruce) and some with decreasing growth trends (balsam fir and sugar maple) dominance of red maple across the region.

landscape productivity models between 2000 and 2012 inform how productivity is changing over time and how this differs across species and locations.



Model of 2012 productivity using the six species with sufficient calibration coverage. Individual species models were averaged to illustrate overall productivity in a given location based on Landfire species distribution maps.

MODELING HEMLOCK WOOLLY ADELGID RISK AND IMPACTS OF PRESALVAGE HARVESTING ON CARBON STOCKS IN NORTHERN HEMLOCK FORESTS

Jennifer Pontius [1,2], Paul Schaberg [2] , William Livingston [3], Kara Lorion[3], Stacy Trosper[3]

[1]UVM Rubenstein School of Environment and Natural Resources, 85 Carrigan Dr. Burlington, VT 05405 USA
Jennifer.pontius@uvm.edu
[2]USFS Northern Research Station
[3] University of Maine, Forestry Program

ABSTRACT

Two recent studies provide useful information on the management of northern hemlock stands in light of encroaching hemlock woolly adelgid (HWA) infestations.

Mapping Hemlock Vulnerability to Hemlock Woolly Adelgid Induced Decline

The purpose of this modeling project is to identify locations across the northeast where hemlock is likely to tolerate HWA infestation under changing climate conditions. Dendrochronological methods provide a more nuanced assessment of HWA impacts on hemlock allowing us to quantitatively identify the onset of infestation and examine the variable rates of growth decline that follow incipient infestation. This information is necessary to

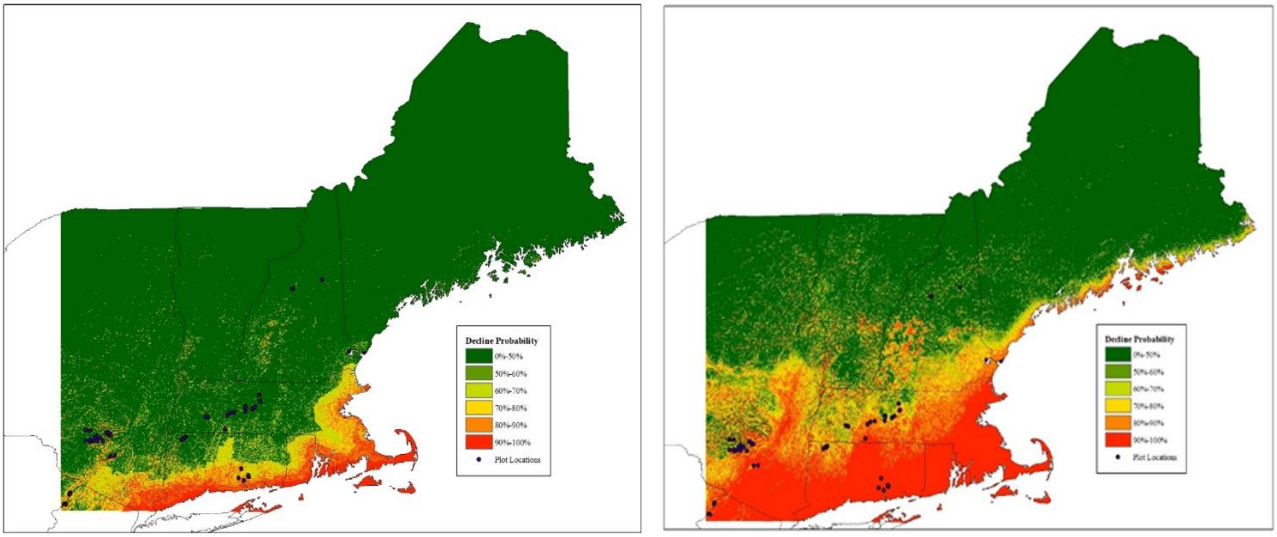
KEY FINDINGS

- Hemlock decline rates following HWA infestation were linked to site characteristics and climate.
- Risk maps generated from these relationships can be used to identify potentially resistant sites.
- Under projected climate conditions hemlock will become vulnerable to more rapid decline across the New England region.
- Simulation models indicate that allowing HWA to progress naturally through a stand may have lower impacts on long-term net C flux than conducting presalvage harvests.
- HWA infestation and presalvage logging will likely result in an increased dominance of red maple across the region.

better understand the variable response of hemlock to HWA, and identify the characteristics of stands with the highest potential for tolerance and recovery.

Historical changes in hemlock radial growth following HWA infestation and drought were linked to site characteristics across the region. Sites with steeper slopes, increased exposure to solar radiation, and warmer January minimum temperatures have a greater probability of experiencing hemlock growth decline in the study region. The resulting model correctly classified 80% of the 41 calibration sites and 73% of the 15 independent validation sites across the region.

Applied to GIS layers we created spatially-explicit maps of the likelihood of rapid hemlock decline if/when HWA arrives. Land managers can use these maps to help prioritize management strategies for addressing sites where hemlock is likely to decline, as well as identifying locations where hemlock is likely to maintain current growth trends. However, the projected increase in January minimum temperatures will result in HWA-incited hemlock growth decline further north and inland than was previously predicted.



Left: *Historical climate risk map shows probable locations of declining sites using logit coefficients applied to three parameters across the New England region: (1) slope, (2) summer hillshade, and (3) 1971-2000 January minimum temperature.* ***Right:*** *Future climate risk map shows probable locations of declining sites for the same model but based on a + 2°C increase over 1981-2010 January minimum temperature normal.*

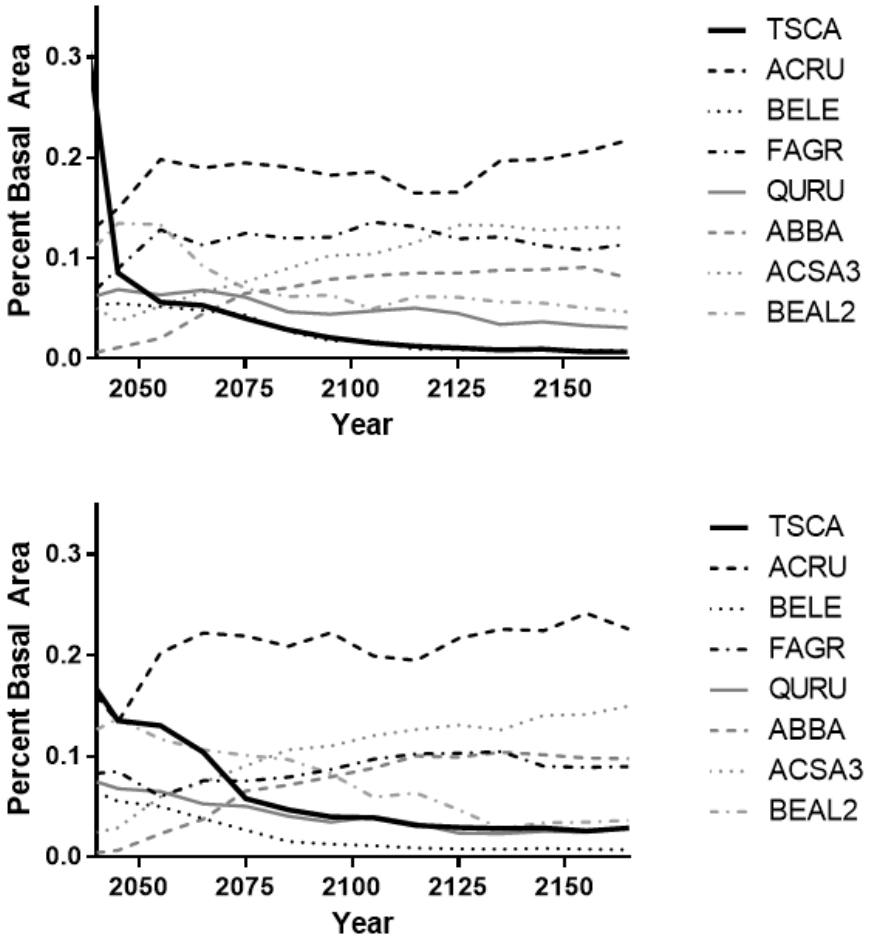
Modeling Long-term Hemlock Carbon Storage

Stand development simulations under various management scenarios allowed us to model the potential impact of HWA infestation and management activities on carbon (C) dynamics in northern hemlock stands. We used FVS and FIA data from across the northeast to model C storage and successional pathways under presalvage harvesting, HWA infestation and no disturbance scenarios over a 150-year simulation.

HWA infestation and presalvage logging will likely result in an increased dominance of red maple across the region. Both presalvage and HWA scenarios had significantly lower total C storage than the control at the end of the 150 year simulation. However, the *cumulative net* C gain was lower for the presalvage than HWA scenario, indicating that allowing HWA to progress naturally through a stand may have lower impacts on long-term *net* C flux than conducting presalvage harvests. While differences were not significant on low hemlock density stands, impacts to the estimated 267,000 hectares of northern New York and New England where hemlock is dominant could result in conversion to red maple and a net loss of over 4 million metric tons of C over the next 150 years.

While these results suggest that C continues to accrue in northern hemlock forests following HWA infestation, long-term there is still a decrease in cumulative net C storage that is likely to result from HWA infestation and associated presalvage harvests, with a potential legacy that persists at least 150 years post disturbance. Considering the low market value of hemlock and the potential for incorporating C markets into revenue streams, allowing HWA-induced mortality to proceed without presalvage logging could become more appealing to land managers as HWA progresses northward.

These studies, along with knowledge of current HWA infestation borders, can be used to direct management efforts, with the intention of minimizing HWA-induced hemlock mortality and maintaining the regions carbon stocks.



*Simulated changes in percent basal area provide an approximation of how species composition may change following HWA **(top)** and presalvage **(bottom)** treatments in northern New York and New England hemlock stands.*

IRREGULAR SHELTERWOOD AS AN ALTERNATIVE TO CLEARCUTTING IN BALSAM FIR-YELLOW BIRCH STANDS

Patricia Raymond, Steve Bédard, Stéphane Tremblay, and Catherine Larouche

Ministère des Forêts, de la Faune et des Parcs, Direction de la recherche forestière, 2700 Rue Einstein, Québec, G1P 3W8, Québec, Canada
Patricia.Raymond@mffp.gouv.qc.ca, steve.bedard@mffp.gouv.qc.ca , stephane.tremblay@mffp.gouv.qc.ca , catherine.larouche@mffp.gouv.qc.ca

ABSTRACT

Even-aged systems have been used for decades in North America for managing conifer-dominated stands with the goal to normalize the forest and reach sustainable wood production. Because of their simplicity of application and the short-term economic benefits, conifer-dominated stands of the boreal and mixedwood forests have been largely managed under even-aged systems. However, the widespread use of clearcutting and its variants have altered many features of these forests at both landscape and stand scales.

Set in 2009, the experiment compare the effects of irregular shelterwood scenarios to careful logging and uncut control stands on the regeneration of balsam fir (*Abies balsamea* [L.] Mill.) – yellow birch (*Betula alleghaniensis* Britton) irregular stands. Scenarios include an uncut control, 25% continuous cover irregular shelterwood (no final cut), 40% extended irregular shelterwood (final cut at year 30), 50% regular shelterwood (final cut at year 10), and careful logging (clearcut with protection of trees ≤ 9.1 cm dbh).

KEY FINDINGS

- Irregular shelterwood scenarios have potential to regenerate conifer-dominated mixedwood stands as an alternative to clearcutting.
- Light shelterwood scenarios successfully established red spruce, balsam fir and yellow birch, while limiting red maple and pin cherry competition.
- However, longer-term observations are needed to identify the best scenarios.

After five years, the 25% continuous cover irregular shelterwood was the most favourable cutting treatment to establish red spruce (*Picea rubens* Sarg.) and balsam fir seedlings (<30 cm). All cutting treatments increased significantly yellow birch seedling density >30 cm. Cutting treatments also

influenced the response of competing vegetation that expanded the most in clearcut cutovers. The lightest 25% shelterwood cut kept the competing species coverage at a level closer to the control and significantly lower than in the clearcut. Up to now, early establishment results indicate that irregular shelterwood scenarios could be helpful to regenerate conifer-dominated mixedwood stands and have potential as an alternative to clearcutting.

Our first five-years results show that the 25% continuous cover irregular shelterwood was the most successful treatment for establishing the three desired species (red spruce, balsam fir and yellow birch), while limiting the expansion of the competition in the understory.

MAINTAINING LOGGER VIABILITY IN THE NORTHEAST

Jamie L. Regula and Rene H. Germain

SUNY ESF, 1 Forestry Dr, Syracuse, NY 13210 USA *jtromble@syr.edu*

ABSTRACT

The economic sustainability of logging businesses is critical to successful forest management and a sustained flow of roundwood to primary wood manufacturers. In recent decades, expectations on loggers have increased because of the expansion of harvesting regulations, including best management practices (BMPs), and the adoption of forest and logger certification programs. Unfortunately, these rising expectations can result in increasing logging costs. Productivity can fluctuate from job to job, depending on some critical factors associated with the harvest, including harvest volume per acre, species, stem size (or average logs per stem), area of sale, average skidding distance, topography, access system, and amount of noncommercial timber stand improvement. The variability of harvesting conditions and associated lack of predictability is particularly acute in hardwood and mixed-wood forest cover types of the Northeast. This study seeks to examine those factors that influence logger profitability from job to job. Working in partnership with sawmill procurement foresters, we interviewed 20 loggers to determine equipment spread, operating and ownership costs, special characteristics of the harvest they recently completed and views on current logging equipment availability. Following the interview, we GPS'd the landing(s) and skid roads, assessing slope, skidding distance, as well as identified BMPs that were implemented. Results will report: 1) individual harvest characteristics influencing logger profitability, 2) determine optimal productivity and price ranges that ensure logger profitability, 3) explore the compatibility of today's logging equipment with declining woodlot sizes and harvest volumes.

COMPARISON OF CRITICAL LOADS OF NITROGEN FOR FOREST SPECIES AND COMMUNITIES IN CLASS I AREAS OF THE NORTHEASTERN UNITED STATES

Molly Robin-Abbott[(1)], Linda H. Pardo[(1)], Jennifer Pontius[(1,2)], Jason Coombs[(1)]

1) *USDA Forest Service, Northern Research Station, 85 Carrigan Dr. Burlington, VT 05405 USA*
mjrobina@gmail.com , lpardo@fs.fed.us , jcoombs@cns.umass.edu
2) *University of Vermont 85 Carrigan Dr. Burlington, VT 05405 USA japontiu@uvm.edu*

ABSTRACT

We have developed a GIS tool (N-CLAS) that allows federal land managers, policy makers, and others to calculate site-based critical loads of nitrogen (N) and exceedance for forested areas in the northeastern United States. N-CLAS is based on species-specific tables that set optimal growth thresholds for multiple soil, site, and climate parameters. The species on a site determine the initial critical load range; site conditions determine whether the critical load is adjusted to the upper part of the critical loads range or the lower part of critical loads range. Critical loads can be calculated for a single species at a site, multiple species, or for the community. The most sensitive species will determine the critical load in the community calculation. Changing site conditions, including climate change, harvesting, insect pests, fungal pathogens, and extreme weather events, will affect site growth conditions, N-cycling, and critical loads. In this poster we use maps and tables generated by N-CLAS to examine the effects of climate change scenarios on adjusted critical loads of N and exceedance for selected species in Class I areas of the Northeastern United States.

LONG-TERM REGENERATION DYNAMICS IN NORTHERN HARDWOOD FORESTS OF THE NORTHEAST

Nicole Rogers[(1)], Anthony W. D'Amato[(1)], Ralph Nyland[(2)], Laura S. Kenefic[(3)] and Mark Twery[(3)]

(1) University of Vermont, Rubenstein School of the Environment and Natural Resources, 85 Carrigan Dr. Burlington, VT 05405 USA nicole.rogers@uvm.edu
(2) SUNY-ESF, Forest and Resources Management
(3) USDA Forest Service, Northern Research Station

ABSTRACT

Establishment of regeneration of desired species and at an adequate stocking is essential to sustainable management of northern hardwood forests in the northeast United States. However, success of natural regeneration can vary depending on site and climatic drivers, and be further complicated by type of regeneration method used. In the Adirondack region of New York, long-term silvicultural studies (>20 years) offer a unique opportunity to explore the dynamics of hardwood regeneration under both even and uneven-aged systems across a range of site and forest conditions. We'll review changes in stocking, density, recruitment and species composition over time and additionally frame findings within the context of current silvicultural practices for northern hardwood forests and the pervasive impacts of beech bark disease on long-term regeneration dynamics. Implications for sustainable management and resiliency of these forests into the future will also be discussed.

INFLUENCE OF LOGGING DISTURBANCE ON TREE GROWTH, SPECIES COMPOSITION, AND RESIDUAL STAND DAMAGE FOLLOWING HARVESTING IN TWO MAINE SPRUCE-FIR STANDS

Roth, B.E.[(1)], Lachance, C[(2)], Wagner, R.G.[(3)], and Benjamin, J.G.[(4)]

[(1)] Cooperative Forestry Research Unit, 5755 Nutting Hall, University of Maine, Orono, ME 04469 USA. brian.roth@maine.edu
[(2)]Weyerhaeuser, 19 Loggers Circle, Bingham, ME 04920 USA. cody.lachance@weyerhaeuser.com
[(3)] Department of Forestry & Natural Resources
Purdue University, West Lafayette, IN 47907 USA. rgwagner@purdue.edu
[(4)] Bangor Christian Schools, 1476 Broadway, Bangor, ME 04401 USA.
jbenjamin@bangorchristian.org

ABSTRACT

Soil Disturbance – Weymouth Point Study:

Mechanized harvesting can lead to a wide range of soil disturbances (including mineral soil exposure, soil compaction, organic matter removal, mounding, and rutting) that can influence subsequent forest composition, structure, or growth. Earlier research has had mixed conclusions regarding the effect of soil disturbance on future forest productivity. We used a long-term experiment in northern Maine to quantify forest productivity for 32 years since clearcut harvesting using a whole-tree harvest system (WT). Soil disturbance measurements were made on 100 transects that were installed immediately after the site was harvested in 1981. We found no influence of soil disturbance on tree- and stand-level variables, including basal area, density, percent hardwood, volume, DBH, and height. We also examined annual radial growth rates using tree cores from a subset of balsam fir crop trees (>6.35 cm DBH) that had grown on the most and least disturbed soil conditions, and found no differences in growth rates over the entire growth period. Despite extensive

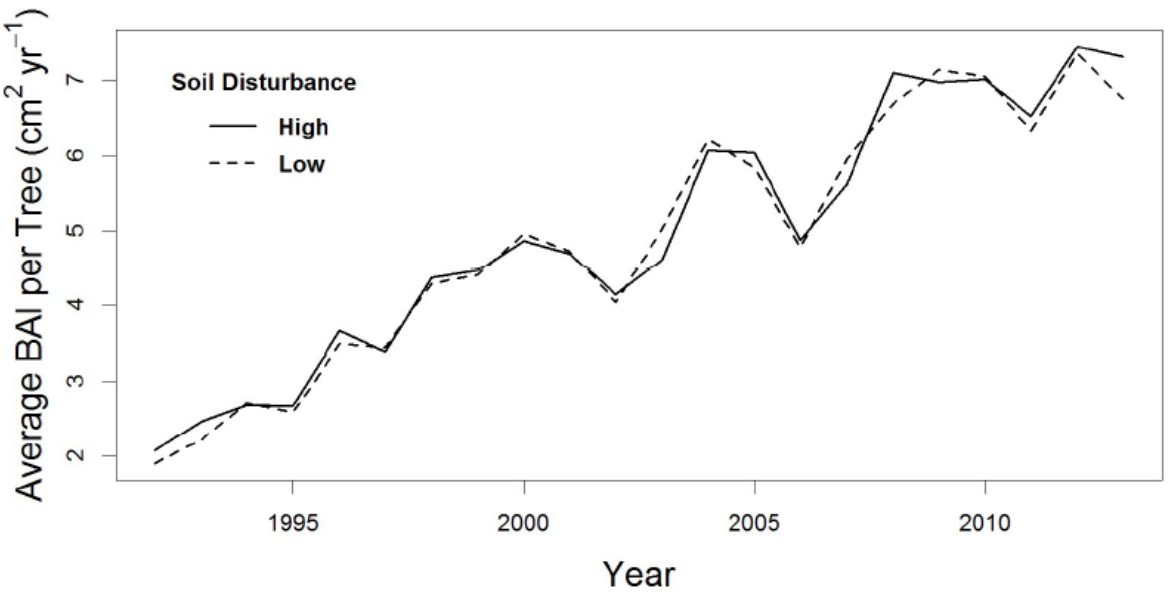
KEY FINDINGS

- Despite extensive rutting at the time of harvesting 32 years earlier, we were unable to detect a reduction in crop tree production or species composition.
- Pre-commercial thinning is an important factor in limiting stem damage during future commercial thinning operations.
- Trees closer to harvest trails had a higher probability of stem and root damage, along with a higher probability of high or medium severity wounds.

soil rutting and mineral soil exposure after WT harvesting, we were unable to detect any differences in subsequent forest composition, structure, or growth from soil disturbance at the Weymouth Point study site 32 years after the harvest.

Residual Stem Damage – Austin Pond Study:

Commercial thinning (CT) and precommercial thinning (PCT) are common silvicultural treatments in the management of spruce-fir stands of the Northeast. The positive effects of CT and PCT on tree growth and financial gain are well documented, but there have been few studies of residual stand damage following these treatments. We used a long-term silvicultural experiment in west-central Maine to quantify stem, root, and crown damage following CT at 33, 50, and 66% levels of relative density reduction in stands that had previously received precommercial thinning (PCT) or no PCT. We found that prior PCT with CTL harvesting was the most important factor predicting the level of residual stand damage after CT. Higher initial densities associated with no-PCT and WT harvesting increased the probability of machine-to-tree or tree-to-tree contact that resulted 86% more residual stem damage. We found that higher CT removal levels (>33%) resulted in higher rates of stem and root damage. We also found that trees closer to harvest trails had a higher probability of stem and root damage, along with the higher probability of high or medium severity wounds.



Average annual basal area increment per tree (cm2 yr-1) by soil disturbance type (High n = 40, Low n = 32) from 1992 to 2013. A linear regression model found no significant difference between BAI of trees on high soil disturbance or low soil disturbance (p = 0.18).

VERMONT'S MANAGED FORESTS AND SOIL CARBON STOCKS: INTERACTION AMONG LAND-USE HISTORY, EARTHWORMS AND SITE

Don Ross

University of Vermont, Department of Plant and Soil Science, Burlington, VT dross@uvm.edu

ABSTRACT

Much of present-day Vermont's forests were cleared for agriculture in the 1700s and 1800s, with associated long-term loss of soil carbon. Net gains in carbon have occurred since reforestation but these gains may be affected by earthworm invasions. We have been monitoring 18 managed forest stands to be able to determine long-term changes in carbon stores. In addition to measuring carbon, we have documented land-use history dating back to colonial times, determined earthworm species and density, measured tree species and site metrics, and measured a suite of soil chemical parameters. We also determined carbon distribution in soil microaggregates in a subset of sites. Prior land-use in the 18 monitored plots included cultivation, pasture, and farm woodlot. Higher earthworm species diversity correlated with reduced forest floor depth, higher mineral soil carbon, and greater stability (microaggregate-protected) of that carbon. Sites with the highest worm density had a history of more intense agricultural land use (although not all former agricultural sites had earthworms). There were also positive interactions between exchangeable calcium pools and earthworm density, and between elevation and carbon in the forest floor. Present-day carbon stores appear to be a complex interaction of land-use history, site location, earthworm history and soil chemistry.

CAN GAP-BASED MANAGEMENT PROMOTE NATURAL REGENERATION AND DIVERSITY IN MIXEDWOOD STANDS?

Alejandro A. Royo[(1)], and Patricia Raymond[(2)]

[(1)]Northern Research Station, Forestry Sciences Laboratory, 335 National Forge Road P.O. Box 267, Irvine, PA, USA, 16329, aroyo@fs.fed.us
[(2)]Ministère des Forêts, de la Faune et des Parcs, Direction de la recherche forestière, 2700 Rue Einstein, Québec, G1P 3W8, Québec, Canada, Patricia.Raymond@mffp.gouv.qc.ca

ABSTRACT

In Quebec (Canada), the yellow birch (*Betula alleghaniensis* Britton) – conifer forest type is the most widespread and economically important in the temperate mixedwood zone. Management goals include sustained wood production, particularly of yellow birch, red spruce (*Picea rubens* Sarg.) and balsam fir (*Abies balsamea* [L.] Mill.) while maintaining overall species diversity, composition and structural heterogeneity. Given the historical importance of naturally occurring canopy gaps in these systems, gap-based silvicultural systems potentially offer a tool to achieve these goals.

Beginning in 2008, we experimentally evaluated the impact of a hybrid single- and small group selection system on regeneration dynamics and plant diversity. Our experiment employs a harvest intensity gradient (Residual BA) consisting of uncut control (26 m²/ha), light (19 m²/ha), moderate (17 m²/ha) and heavy (15 m²/ha) cutting with repeated vegetation censuses at 1, 3, 5 and 8 years post-cut.

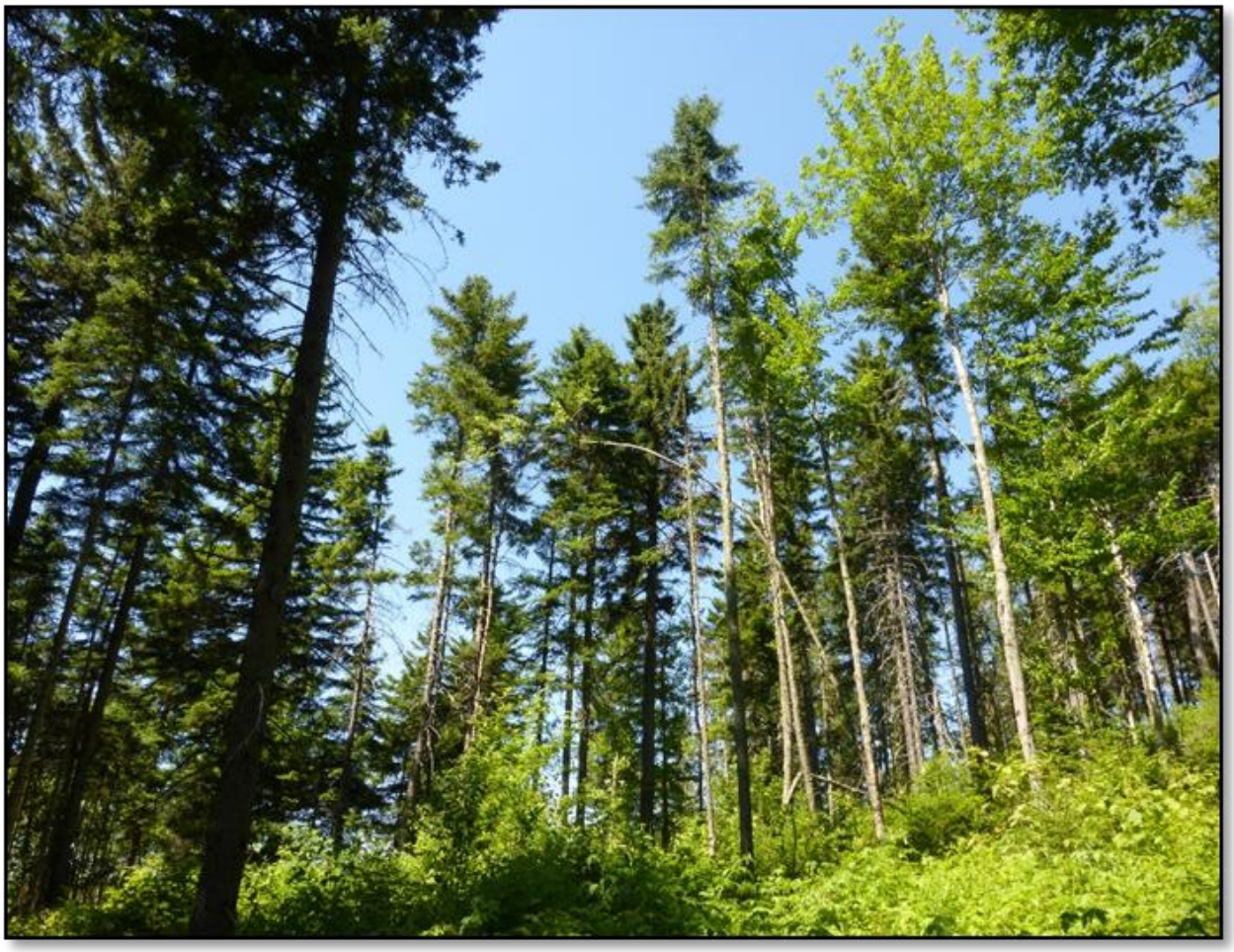
KEY FINDINGS

- Gap-based silviculture can favor yellow birch recruitment without impacting plant diversity.
- However, increasing harvest intensity also enhanced interfering non-commercial species abundance and failed to improve red spruce regeneration.
- Further study will be necessary to evaluate thresholds to achieve both regeneration and diversity goals.

Greater harvest intensities enhanced overall plant cover across the 8-yr period (significant Treatment×Year interaction). Heavier harvest intensities increased diversity. Species richness increased irrespective of harvest intensity. Observed richness and diversity gains were driven by augmented yellow birch, mountain maple (*Acer spicatum* Lam.) and pin cherry (*Prunus pensylvanica* L. f.)

recruitment into larger classes as well as greater forb, tree and shrub cover over time in response to greater harvest intensities. In contrast, harvesting did not affect forb, shrub and fern richness.

Our 8-yr results show gap-based treatments can favour yellow birch recruitment without negatively impacting plant diversity in this forest type. Indeed, heavier harvest intensities augmented overall plant diversity and tree richness. Nevertheless, because increasing harvest intensity simultaneously enhanced interfering non-commercial tree species abundance (e.g. mountain maple) and failed to improve red spruce regeneration, we caution that further study will be necessary to evaluate if and at which thresholds both regeneration and diversity goals can be achieved.



Our 8-yr results show that the hybrid single- and small group selection system, a gap-based approach, could be used to achieve both regeneration and diversity goals in yellow birch-conifer stands.

THE LONG-TERM EFFECTS OF LOGGING, HURRICANE DISTURBANCE, AND SALVAGE LOGGING ON OLD-GROWTH FOREST STANDS IN NEW HAMPSHIRE

Emma M. Sass[(1)], Anthony W. D'Amato[(1)]

[(1)]University of Vermont, Aiken Center, Burlington, Vermont, USA 05401
esass@uvm.edu , awdamato@uvm.edu

ABSTRACT

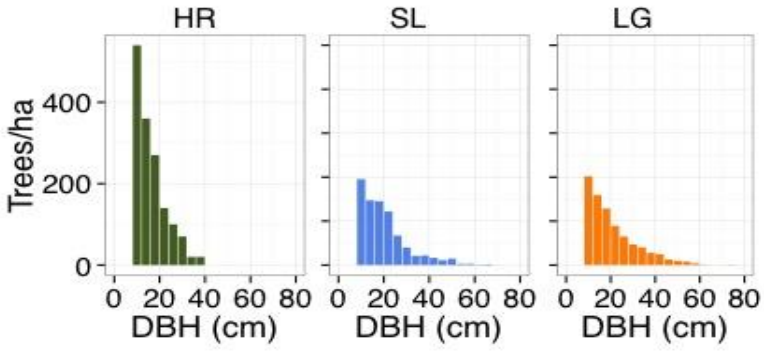
Salvage logging is a common post-disturbance management practice; short-term effects are well documented but longer-term effects remain less well known. In Pisgah State Park, NH, we compared the structure and composition of old-growth stands from 1930 to those developing following 1) logging in the 1920s (LG), 2) severe damage from the 1938 hurricane (HR), and 3) severe damage from the hurricane and subsequent salvage logging (SL). The HR plot represented a unique case study that served as a benchmark of long-term forest response to hurricane disturbance.

KEY FINDINGS

- Live tree structure is the least developed in the hurricane-damaged stand.
- CWD is highest in unsalvaged, unlogged areas.
- Composition has not returned to pre-disturbance.

The HR plot had the highest density of trees (1520 stems/ha) compared to salvaged (342±98) or logged areas (818±40) 78 years following disturbance. The fewer but larger trees in salvaged and logged sites imply a more mature live tree structure than the HR plot. Coarse woody debris (CWD) biomass was highest in the HR plot (12.0 Mg/ha). HR also had the greatest density of pit and mound structures (115/ha), followed by salvaged (73/ha) and logged areas (11/ha). This study builds on our understanding of salvage logging effects and provides an extended temporal view on compositional and structural differences that persist after singular and compound disturbances.

Diameter distributions for three management histories at Pisgah State Park, NH. HR= damaged by the 1938 hurricane; SL=hurricane damaged and salvage logged: LG=logged prior to the 1938 hurricane.



BUILDING A DENDROECOLOGY DATABASE FOR THE NORTHERN FOREST

Paul Schaberg[1], Shelly Rayback[2], Christopher Hansen[3], Paula Murakami[1], James Duncan[3, 4], Alexandra Kosiba[3], Benjamin Engel[3], Rebecca Stern[3], Gary Hawley[3], Jennifer Pontius[1, 3, 4]

(1)US Forest Service, Northern Research Station, 81 Carrigan Dr., Burlington, VT 05405, USA, pschaberg@fs.fed.us, pmurakami@fs.fed.us

(2)University of Vermont, Department of Geography, 94 University Pl., Burlington, VT 05405, USA, srayback@uvm.edu

(3)University of Vermont, Rubenstein School of Environment and Natural Resources, 81 Carrigan Dr., Burlington, VT 05405, USA, chansen@uvm.edu , akosiba@uvm.edu , bengel@uvm.edu rstern1@uvm.edu ghawley@uvm.edu , jpontius@uvm.edu

(4)Vermont Monitoring Cooperative, 705 Spear St., South Burlington, VT 05403, USA james.duncan@uvm.edu

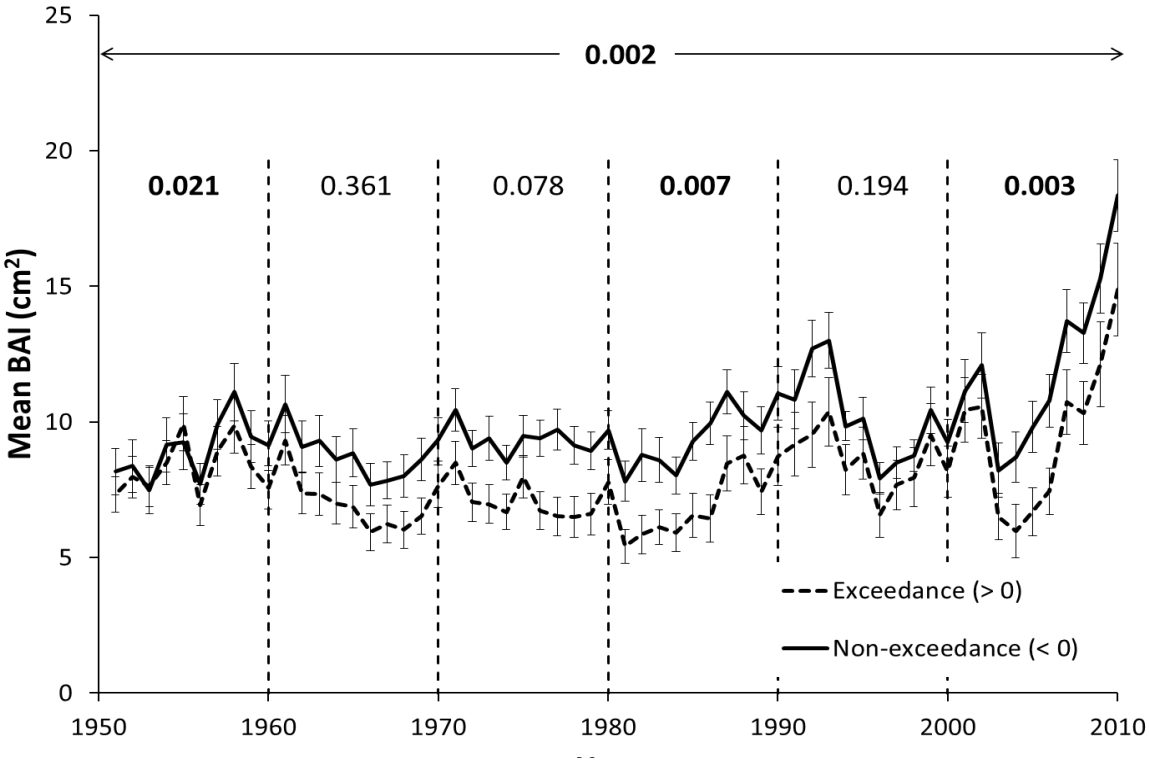
ABSTRACT

We are establishing a dendroecology database that will combine tree-ring growth and ecological data for a wide range of species and sites across the region. Initial work involves comparing growth among species and locations, assessing changing trends in growth, and evaluating if ancillary site and environmental factors are associated with growth trends. Two examples of studies within the Northern Forest were presented to highlight the potential value of the database. The first involved the use of red spruce tree-ring chronologies to field-test a steady-state sulfur and nitrogen pollution critical load exceedance model for the region. Results indicated that critical load exceedance was associated with reduced growth over the past 60 years, but that trees are now growing better than they have over the entire chronology. The second used tree rings from five species to assess which climate variables best accounted for patterns of growth on Vermont's tallest mountain – Mount Mansfield.

KEY FINDINGS

- Tree rings reflect the influence of the environment on growth.
- Past work has shown how pollution loading and temperature alter growth.
- New work will evaluate growth and its drivers for many species and locations.

Results indicate that increased growth was broadly associated with higher temperatures.



Mean (±SE) basal area increment (BAI) for 441 red spruce trees at 37 sites in Vermont and New Hampshire that exceeded or did not exceed modelled sulfur and nitrogen pollution critical loads. Trees in non-exceedance plots had higher growth for the 60-year period overall and for decades with more severe or frequent foliar winter injury. Statistically significant P-values (P ≤0.05) are in bold.

LOCAL ADAPTATION OF TREES AT THE RANGE MARGINS SLOWS RANGE SHIFTS IN THE FACE OF CLIMATE CHANGE

Kevin Solarik

Université du Québec à Montréal, Department of Biological Science Montréal, Québec, Canada
kevinsolarik@hotmail.com

ABSTRACT

The inability of certain species to track their climatic niche at rates comparable to climate change is concerning, particularly if those species are constrained due to their adaptation at the local scale within their current range. In long-lived, sessile organisms such as trees, genetic adaptation is slow, and our knowledge of the relative contribution of the driving factors which control range expansion is lacking. Here, we conducted a species wide seed transplant experiment to investigate a series of contributing factors potentially constraining species range expansion in early tree seedling establishment phases. We find a combination of provenance, climatic, and microsite factors all play a profound role in the ability of a species to migrate northward in latitude, where the contribution of each of these factors changes depending on the environment at the local scale. First, we found that seed provenance from the northern portion of the range provides currently the best opportunity to establish beyond the current range, where climatic conditions are more similar than those of the central or southern portions of the species range. We found that although seedling establishment was highest within the species range, survival rates were comparable to those at the range margin and beyond, regardless of where the seed originated. We find that local climate was the most influential factor for establishment and survival within and at the species range margin, however, microsite drove recruitment beyond the range boundary. Ultimately, recruitment failure will occur if the climate changes at a rate superior to the adaptive capacity of the species to novel climatic conditions.

ASSESSING LONG TERM IMPACTS OF INTERMEDIATE TREATMENTS ON TIMBER QUALITY AND STAND ECOLOGY OF NORTHERN HARDWOOD FORESTS IN NEW HAMPSHIRE

Meghan Thornton and Ted Howard

University of New Hampshire, Durham, NH 03825 USA ted.howard@unh.edu

ABSTRACT

The primary intermediate treatments used in northern hardwood forest management are pre-commercial and commercial thinning. These methods can be used to improve forest stand quality or promote growth of desired species. In northern hardwood forests, pre-commercial thinning involves killing or removing competing trees from around selected crop trees. However, depending on landowner objectives, intermediate treatments might not provide a financial or ecological return that justifies the harvesting operation. The research area is an above-average hardwood site located in the Bartlett Experimental Forest (BEF) in Bartlett, New Hampshire. A clear cut of the stand occurred in 1935, a crop tree release using four treatments occurred in 1959 at age 25, and a dominant tree removal of paper birch and aspen occurred in 2003 at age 69. Previous research includes data on stand growth, species composition, and volume change spanning 80 years, as well as two financial analyses on the pre-commercial work. This research proposes an assessment of standing timber quality within and among the treatments, as well as an ecological assessment of coarse woody debris and snag recruitment. It also proposes a financial analysis post-2003 commercial thinning that considers the market for sawlogs over the declining market for boltwood.

EFFECTIVE LANDOWNER ENGAGEMENT - FROM OUTREACH TO OUTCOMES

Mary Tyrrell, Purnima Chawla and Emma Kravet

Yale School of Forestry & Environmental Studies 195 Prospect Street, New Haven, CT 06511 USA
mary.tyrrell@yale.edu

ABSTRACT

Two of the biggest challenges to improved stewardship and conservation on private lands are 1) getting the attention of the landowners (outreach) and 2) getting them to take action (outcomes). Both require focused, targeted effort to understand the landowners - their attitudes, values, needs and priorities - and getting a good match between stewardship and conservation program objectives and the needs and desires of the landowners. We will share learnings from the Sustaining Family Forests Initiative research on family landowners and from working with natural resource professionals in over 300 organizations throughout the US to develop effective landowner engagement programs. Conservation and stewardship actions often require a large and long-term commitment which landowners may view as too difficult or risky. The most efficient and effective outreach programs target their efforts towards the landowners who are most likely to engage in the desired behavior and (or) to those who have the greatest impact on the program goals. A successful outreach program focuses on key motivations of the target audience and addresses ways to overcome the most obvious barriers in order to persuade landowners to take action. There are a range of data that can and should be used to understand landowner motivations and barriers to action, including quantitative data (surveys) and qualitative data (focus groups). By presenting several case studies, we will discuss how targeted marketing and landowner data are being used in various outreach campaigns, and the evaluation process and measures that organizations are using to track outcomes.

FOREST STRUCTURAL DEVELOPMENT AND CARBON DYNAMICS AS INFLUENCED BY LAND-USE HISTORY AND REFORESTATION APPROACH

Andrea Urbano

UVM Rubenstein School of Environment and Natural Resources, 85 Carrigan Dr. Burlington, VT 05405 USA arurbano@uvm.edu

ABSTRACT

Temperate forests are an important carbon sink, yet uncertainty remains regarding land-use history effects on biomass accumulation and carbon storage potential in secondary forests. Improving this understanding is vital for managing forests as carbon sinks and is possible by studying long-term northeastern U.S. forest recovery post nineteenth century agricultural abandonment. We employed a longitudinal study based on 12 years of empirical data (2001-2013) collected from 60 monitoring plots within 16 reference stands at Marsh-Billings-Rockefeller National Historical Park in Woodstock, VT and 150 years of documentary data from park management records. We evaluated the effects of reforestation approaches (planting vs. natural regeneration), management (long-term low harvest intensities at varied frequencies), and stand development pathways on biomass outcomes. We generated biometrics indicative of stand structural complexity (H' index) and aboveground biomass (live trees, snags, and downed coarse woody debris pools) estimates. Multivariate analyses evaluated the predictive strength of reforestation approach, management history, and site characteristics relative to aboveground carbon pools and stand structural complexity.

Classification and Regression Tree (CART) analysis ranked reforestation method as the strongest predictor of mean total aboveground carbon storage, and selected harvest frequency and stand age as secondary variables. CART ranked percent conifer as the strongest predictor of H', and harvest intensity and frequency as secondarily predictive. A variety of long-term recovery pathways converge on high levels of aboveground carbon storage, but silvicultural management can dramatically alter those trajectories. Our dataset showed a positive relationship between forest carbon storage and structural complexity (r2=0.25), supporting multifunctional forestry emphasizing late-successional habitats.

CLIMATE CHANGE ADAPTATION BY VERMONT SNOWMOBILERS

William Valliere, Robert Manning, Elizabeth Perry, Xiao Xiao, Nathan Reigner

University of Vermont, Parks Studies La, 85 Carrigan Dr. Burlington, VT 05405 USA
wvallier@uvm.edu

ABSTRACT

Ecosystems provide a many services to society, including outdoor recreation. Snowmobiling is an important form of winter recreation, and a vital part of Vermont's winter tourism economy. Climate change may substantially alter use of Vermont's extensive system of snowmobile trails. In order to continue to serve the needs of snowmobilers, management of the trail system must adapt to a changing climate and evolving patterns of use. To help inform adaptive management and as part of a larger decision support tool, a survey of members of the Vermont Association of Snow Travelers (VAST) was conducted. The survey asked respondents to report the ways in which they would adapt their use of the snowmobile trail network to multiple manifestations of climate change, including temperature, snowfall, distance to trails, landscape types, presence or absence of wildlife, trail encounters, and extent of the available trail network. The goal of the survey was to determine under what conditions use of the snowmobile trail system in Vermont increases and decreases. Baseline information about current use levels and types of use, changes in the trail system and weather over the years was also collected. The online survey was administered to a sample of VAST members for whom the association maintains email records. An email invitation and a reminder email resulted in 1447 completed questionnaires. Study data offer insights into how winter outdoor recreation activities and patterns are likely to evolve in association with a changing climate and how Vermont might best adapt to meet changing demand.

GROWTH RATES OF MAPLE TREES TAPPED WITH HIGH-YIELD SAP COLLECTION PRACTICES – ARE EXISTING TAPPING GUIDELINES SUSTAINABLE?

Abby van den Berg[(1)], Timothy Perkins[(1)], Mark Isselhardt[(1)], Timothy Wilmot[(1)]

(1) University of Vermont Proctor Maple Research Center, P.O. Box 233 Underhill Center, VT 05490, avan@uvm.edu, Timothy.Perkins@uvm.edu , Mark.Isselhardt@uvm.edu , Timothy.Wilmot@uvm.edu

ABSTRACT

Maple syrup production is a traditional practice throughout the northeastern United States and Canada that generates jobs, provides income, and helps maintain the traditional working landscape of the region. The profitability and long-term economic sustainability of maple syrup production depend entirely on the sustainability of annual sap extraction from trees. To be sustainable, annual sap collection must not remove or damage more wood than can be replaced by annual growth, or extract a portion of carbohydrate resources large enough to reduce growth rates and hinder the replenishment of conductive wood. Maple producers follow tapping guidelines, a set of best practices for sap collection, to ensure their practices meet these requirements. Now, however, modern sap collection equipment and practices facilitate at least twice the volume of sap extraction per tree than was possible with the technology used when the existing guidelines were developed.

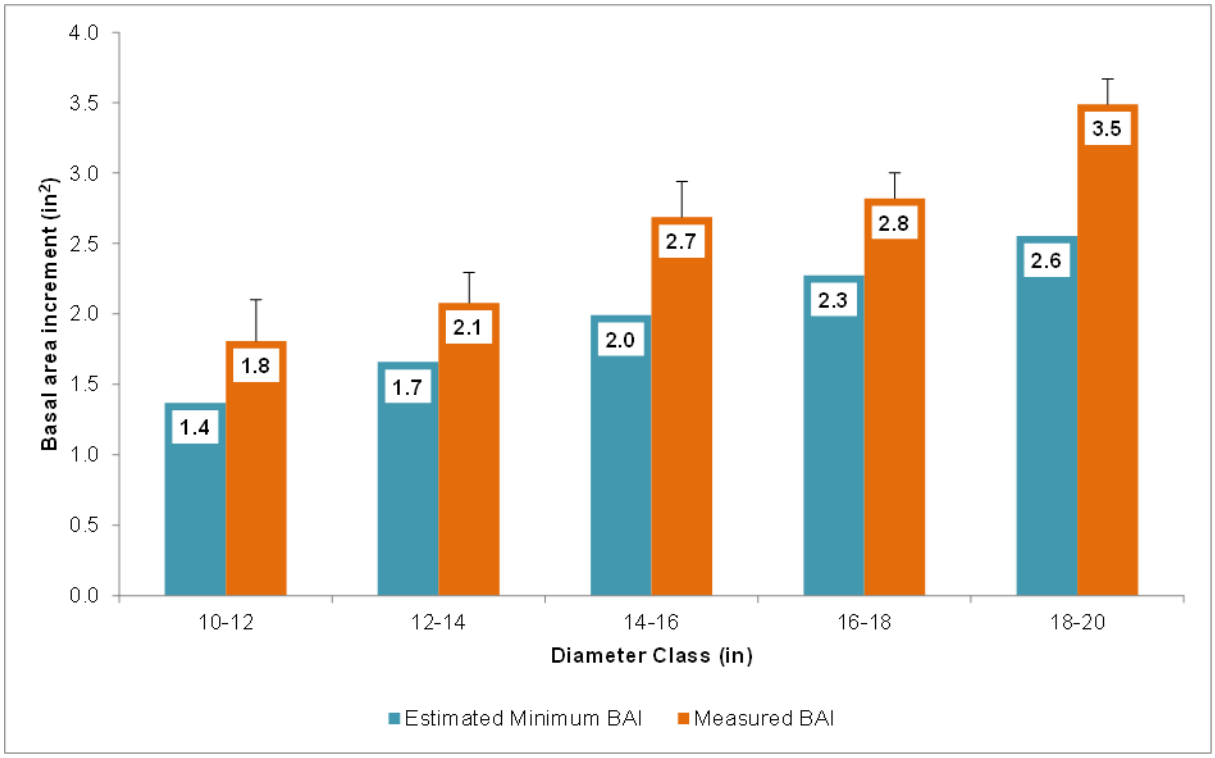
KEY FINDINGS

- Existing tapping guidelines can be appropriate for current collection practices.
- Healthy, dom/codom trees' growth rates often sufficient for sustainable outcomes.
- Int/supp and smaller-dbh trees' growth rates frequently lower than adequate .
- Growth rates should be measured to ensure sustainable tapping and sap collection.

To assess whether the existing tapping guidelines represent a sustainable approach when applied with these current "high-yield" practices, the growth rates of trees tapped with these practices at 18 sites in Vermont were measured, and a model that estimates the availability of conductive wood in the tapping zone of a tree over time was used to determine whether these growth rates were sufficient for the

replenishment of conductive wood to remain at sustainable levels when following the current maple industry tapping guidelines. The basal area increments of healthy, codominant or dominant trees across the sites ranged from 1.8 in^2/yr in 10-in. diameter trees, to 3.5 in^2/yr in 18-in. diameter trees. Estimated minimum growth rates required ranged from 1.4 in^2/yr in 10-in. trees, to 2.6 in^2/yr in 18-in. trees.

These results suggest that the growth rates of many trees tapped with high-yield sap collection practices are sufficient for this activity to remain sustainable when current tapping guidelines are followed. However, an average of 35% of sampled co-dominant and dominant trees, 38% of smaller-diameter (8.0-9.9-in dbh) trees, and between 50 and 82% of trees with intermediate or suppressed canopy position, had growth rates below the estimated minimums. This indicates that for some trees, tapping practices must be modified from those specified in the current guidelines in order ensure adequate replenishment of conductive wood is maintained. Likewise, this indicates that to be certain sustainable tapping practices are implemented, growth rates must be measured.



Overall mean growth rates (basal area increment, BAI) from 2005-2009 of sugar maple trees tapped with high-yield sap collection practices across 18 sites in Vermont (error bars indicate standard error of the mean), and estimated minimum growth rates required for tapping to be sustainable when trees are tapped following existing tapping guidelines. Measured trees had codominant or dominant canopy position and had been tapped annually with a single spout for at least 10 years.

NORTHERN WHITE CEDAR PLANTATIONS: GLORIFIED HEDGES OR A SUITABLE TOOL FOR CEDAR RESTORATION AND FOREST MANAGEMENT?

Olivier Villemaire-Côté[(1)], Jean-Claude Ruel[(1)], Luc Sirois[(2)]

[(1)]Université Laval, 2405 Rue de la Terrasse, Quebec (QC) Canada G1V 0A6 ,
Olivier.Villemaire-Cote.1@ulaval.ca,
Jean-Claude.Ruel@sbf.ulaval.ca
(2) Université du Québec à Rimouski, 300 Aleé des Ursulines, Rimouski (QC), Canada, G5L 3A1
luc_sirois@uqar.ca

ABSTRACT

Northern white cedar (*Thuja occidentalis*, hereafter referred to as cedar) has seen, for several decades and throughout its range, a clear decline in abundance compared to pre-colonial times. Indeed, a lack of seed trees, difficulties in the establishment of natural regeneration and high browsing pressure are observed in most of its range. Typically found as a minor component of mixed species stands, the shade-tolerant, slow-growing cedar generally becomes dominant on mesic soils after succeeding to shorter-lived species. Despite the cultural, ecological and economic importance of northern white cedar, forest management has consequently been more focused on its softwood and hardwood competitors. Not only has this hindered the potential for an increase in cedar abundance, but it has also limited the development of scientific knowledge on cedar management.

KEY FINDINGS

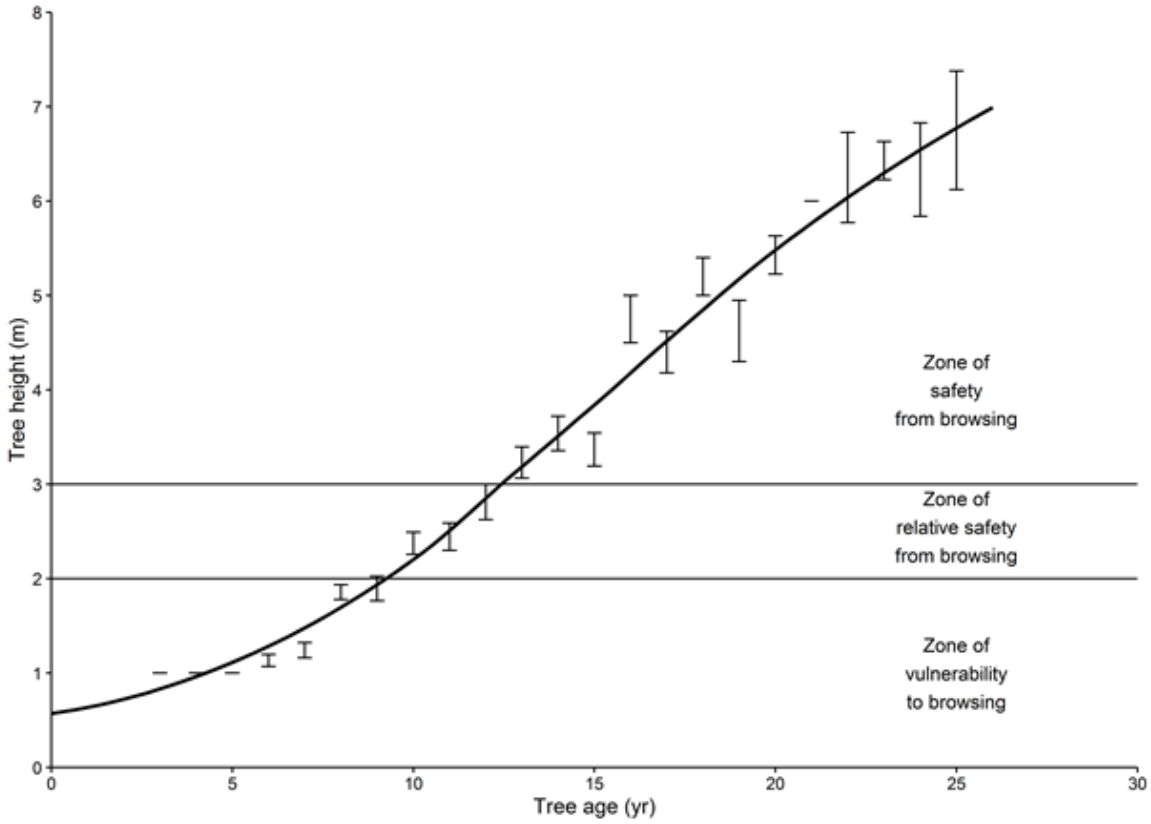
- Planted cedar can grow 8 meters in height and 18 cm in DBH by age 25.
- 10 years of browsing suppression could be sufficient for cedar recruitment.

This study is part of a larger project aimed at developing the scientific basis for sustainable management of cedar. More specifically, its purpose is to generate knowledge on the development of pure and mixed cedar plantations after clearcut to evaluate their suitability in actively restoring the species. Cedar plantations ranging from 5 to 27 years old and located in Eastern Quebec were sampled in the summer of 2015. The effects of browsing pressure, competition and silvicultural treatments on cedar growth and bole forking were studied.

Results show that cedar growth can be substantially faster than what is suggested in the literature, with root collar diameter growth exceeding 1 cm/year and height growth exceeding 25 cm/year on the best

sites. Results also confirm that cedar has a good response to silvicultural treatments such as brushing or thinning. On some sites, planted cedars were found in an intermediate position under shade-intolerant hardwoods, reaching 7 to 8 m in height and 16 to 18 cm in diameter at breast height (DBH) at 27 years old, which suggests that planted cedar can perform well in the presence of shade-intolerant competition.

Zones of safety and vulnerability from and to browsing were drawn according to deer and hare winter browsing reach, which goes up to a maximum of 2.25 m with high snow cover (Figure 1). When trees have reached the zone of safety, at a height of 3 m, they have 1 m of live crown under the worst browsing scenarios, which should guarantee their survival even under high-browsing pressure. The zone of relative safety extends from 2 to 3 m, at which height browsing should predominantly occur on lower branches and should not affect survival except under high-browsing scenarios. Non-suppressed cedars took on average 9 years to reach the zone of relative safety from browsing and 12.5 years to reach the zone of safety from browsing. With cedar generally being browsed in the winter when other food sources are scarce and short seedlings of up to 30 cm in height generally not being available for winter browsing because of snow cover, these results suggest that a well-timed 10 to 13 year predator exclusion could be sufficient for cedar recruitment depending on browsing pressure.



Height-Age curve for non-suppressed northern white cedar plantations in Eastern Québec. Bars correspond to standard errors. Relative safety from browsing is attained at a height of 2 m, and safety from browsing is attained at a height of 3 m.

Although cedar growth is shown to be faster than in the literature, it is still outcompeted. When these competitors are spruce or fir, a dense evergreen multi-layered stand can be created. This stand can be a good winter habitat for hare, an underestimated cedar browser, as fir and spruce will provide cover. A window of vulnerability can therefore be created if cedar is not tall enough when the cover becomes suitable for hare. Moreover, the timing of early silvicultural treatments is more complex to manage in these stands because of differences in growth rates, potentially leading to consequences for cedar as faster growing species might be privileged by forest managers.

Knowledge about cedar plantations is still limited and should be further developed. Indeed, the small pool of older cedar plantations and the lack of historical data prevents the drawing of clear conclusions on some matters. For instance, cedar is known to have a high tendency to fork, and while forks were observed in greater proportions on some sites, no clear correlations could be traced. Similarly, while browsing was observed, the absence of a detailed browsing history prevents detailed conclusions on the effects of browsing on cedar plantations development.

GROWTH AND YIELD OF A JAPANESE LARCH (*LARIX KAEMPFERI* (LAMB) CARIERE) PLANTATION: 75-YEAR RESULTS FROM UNIVERSITY OF VERMONT'S JERICHO RESEARCH FOREST

Justin Waskiewicz, Lindsay Cotnoir and Ralph Tursini

University of Vermont, Rubenstein School of Environment and Natural Resources 85 Carrigan Dr. Burlington, VT 05404, USA *jwaskiew@uvm.edu*

ABSTRACT

The exotic larch species Japanese larch, European larch (*L. decidua* P. Mill), and their hybrid (*L. x marschlinsii* Coaz) are known for high productivity potential in plantations. Exotic larches have been planted in New England for over 100 years, with tens of thousands of acres of these species planted on private, industrial, and some public lands in New England and the Maritime provinces of Canada. Recent interest in exotic larches has spurred a re-examination of plantations across New England. University of Vermont's Jericho Research Forest (JRF) includes one of oldest stands of Japanese larch with an intensive record of management and measurement. Originally established in 1941 on abandoned farmland, the JRF plantation has been re-measured on permanent plots from the mid-1950s to the mid-1990s, a time span including three harvest operations. We examined past data records and a recent re-measurement to reconstruct diameter, height, and volume growth rates for the stand through the present. The trees now average 17.4 inches (44.2cm) DBH and 107 feet (32.6 m) height, and have produced a net total of 8,851 ft3/ac (619.5 m3/ha). Mean annual cubic foot volume production peaked around 1970 at 151 ft3/ac (10.6 m3/ha), whereas mean annual board foot volume growth, at 433 bf/ac (2.53 sawn m3/ha) has not yet peaked. The JRF larch stand provides a unique case study demonstrating the long-term growth potential of this species in New England.

FOREST STRUCTURE, COMPOSITION, AND REGENERATION FOLLOWING WIND DISTURBANCE IN MIXED HARDWOOD-CONIFER ECOSYSTEMS

Aaron Weisinger-Flood, Garrett Meigs and William Keeton

Rubenstein School of Environment and Natural Resources, University of Vermont
Gund Institute for Ecological Economics, 85 Carrigan Dr. Burlington, VT 05405 USA
aaron.weisinger-flood@uvm.edu

ABSTRACT

Wind storms (i.e., blowdown events) are important natural disturbances worldwide, and blowdown frequency or severity may increase with anthropogenic climate change and land use. In this study, we quantify blowdown effects on structural complexity, species composition, and tree regeneration in mature temperate forests spanning a range of blowdown patch sizes in the northeastern United States. We compare wind-affected forests and adjacent reference conditions, assessing variability within and among four sites up to eight years post-blowdown. We find that recent blowdown events transferred a substantial proportion of canopy trees to down coarse woody debris (CWD). On average, the initial post-wind ratio of CWD volume to standing tree volume was 7.09 in blowdown stands and 0.63 in reference stands. Concurrently, the variability of canopy closure within blowdown patches (CV among plots) was 16% higher, indicating diffuse edge conditions. Despite these structural changes, however, tree species composition was generally similar between blowdown and reference conditions across all sites, with generally shade-tolerant species dominating all strata (overstory, saplings, and seedlings). Our findings suggest that intermediate-intensity wind events can increase structural complexity without altering successional dynamics. Specifically, recent blowdowns increased down CWD and canopy gap heterogeneity, two key indicators of late successional forest structure that contemporary forest management activities aim to restore. In addition, the lack of shade-intolerant tree regeneration indicates that species composition at these sites is relatively resistant to wind-induced changes. This study demonstrates how partial canopy disturbances like blowdown can enhance late-successional forest conditions while contributing to stand- and landscape-scale heterogeneity.

STRUCTURAL CHARACTERISTICS OF OLD- AND SECOND-GROWTH NORTHERN WHITE-CEDAR STANDS

Nathan Wesely[(1)], Laura S. Kenefic[(2)], Shawn Fraver [(1)]

[(1)]*School of Forest Resources, University of Maine 5755 Nutting Hall, Orono, ME, 04469 USA*
nathan.wesely@maine.edu

[(2)]*U.S. Forest Service, Penobscot Experimental Forest, 686 Government Road, Bradley, ME USA 04411,*
lkenefic@fs.fed.us

ABSTRACT

Northern white-cedar (NWC) has received limited research attention, and land managers are confronted with challenges when managing cedar, including the recognition of old-growth (OG) characteristics and the differentiation between OG and second-growth (SG) stands, particularly in the context of Forest Stewardship Council (FSC-US) certification. To identify the structural characteristics unique to old-growth NWC stands, we inventoried 16 OG stands and 17 SG stands (those that have been partially harvested) in Maine and New Brunswick. Potential predictors used in the analysis included common structural metrics such as basal area (BA, m^2 ha-1), quadratic mean diameter (QMD, cm), large tree (>= 40 cm dbh) density, volumes of dead wood (m^3 ha-1), along with spatially explicit structural complexity indices (e.g., diameter distribution index, mingling index). Using a generalized linear mixed-model approach, two significant predictors were identified that in combination differentiate OG from SG NWC stands: advanced decay dead wood volume (logs in decay stages 4 and 5 using a 5 decay class system) and live tree QMD. Advanced decay dead wood volumes averaged 60.6 and 20.8 m^3 ha-1, and QMD averaged 29.4 and 26.3 cm for OG and SG stands respectively. Surprisingly, no spatially explicit structural complexity indices were useful in predicting OG status. Our research shows that two measures commonly applied in forest management can be used in the identification of OG NWC stands.

DETERMINING THE MECHANISM OF IMPACT OF HARDWOOD CONTENT ON SPRUCE BUDWORM DEFOLIATION OF BALSAM FIR

Bo Zhang[(1)], David MacLean[(1)]

[(1)] *Forestry and Environmental Management, University of New Brunswick, P.O. Box 4400, Fredericton, NB, E3B 5A3, Canada*
macleand@unb.ca

ABSTRACT

Balsam fir *(Abies balsamea* (L.) Mill.) in mixedwood forests and landscapes with higher hardwood content has been reported to have lower susceptibility and vulnerability than fir-dominated ones during spruce budworm (*Choristoneura fumiferana* (Clem.)) outbreaks. Studies have suggested that the hardwood "protective" effects have been attributed to higher parasitism rates of budworm and/or greater larval dispersal losses with higher hardwood percentage. In this research, a field study was conducted in the Gaspé area, Quebec, where a spruce budworm outbreak started in 2012, to examine budworm-caused fir defoliation among different stand types and to explore the mechanism of the hardwood "protective" effects. Three fir-hardwood stands in each of three hardwood content levels (0-25%, 40-65%, and 75-95%) were selected to compare balsam fir defoliation, budworm population, and parasitism rate on budworm. Ground traps were deployed to assess budworm first and second instar larval dispersal. Preliminary results interpreted from 2013 to 2015 data showed that balsam fir defoliation increased over the three years and peaked in 2015, during which mean annual defoliation for all sampled stands reached 66%. Regression analyses demonstrated significant ($p < 0.01$) negative relationships between defoliation and hardwood content for 2013 and 2014, but were not significant for 2015. Regression slopes indicated that the hardwood "protective" effect was strongest in 2014. Mean annual defoliation for softwood stands was about 20% and 60% higher than in mixedwood and hardwood stands, respectively, in 2014. Differences in spruce budworm population, parasitism and dispersal data as a function of hardwood content will be described.