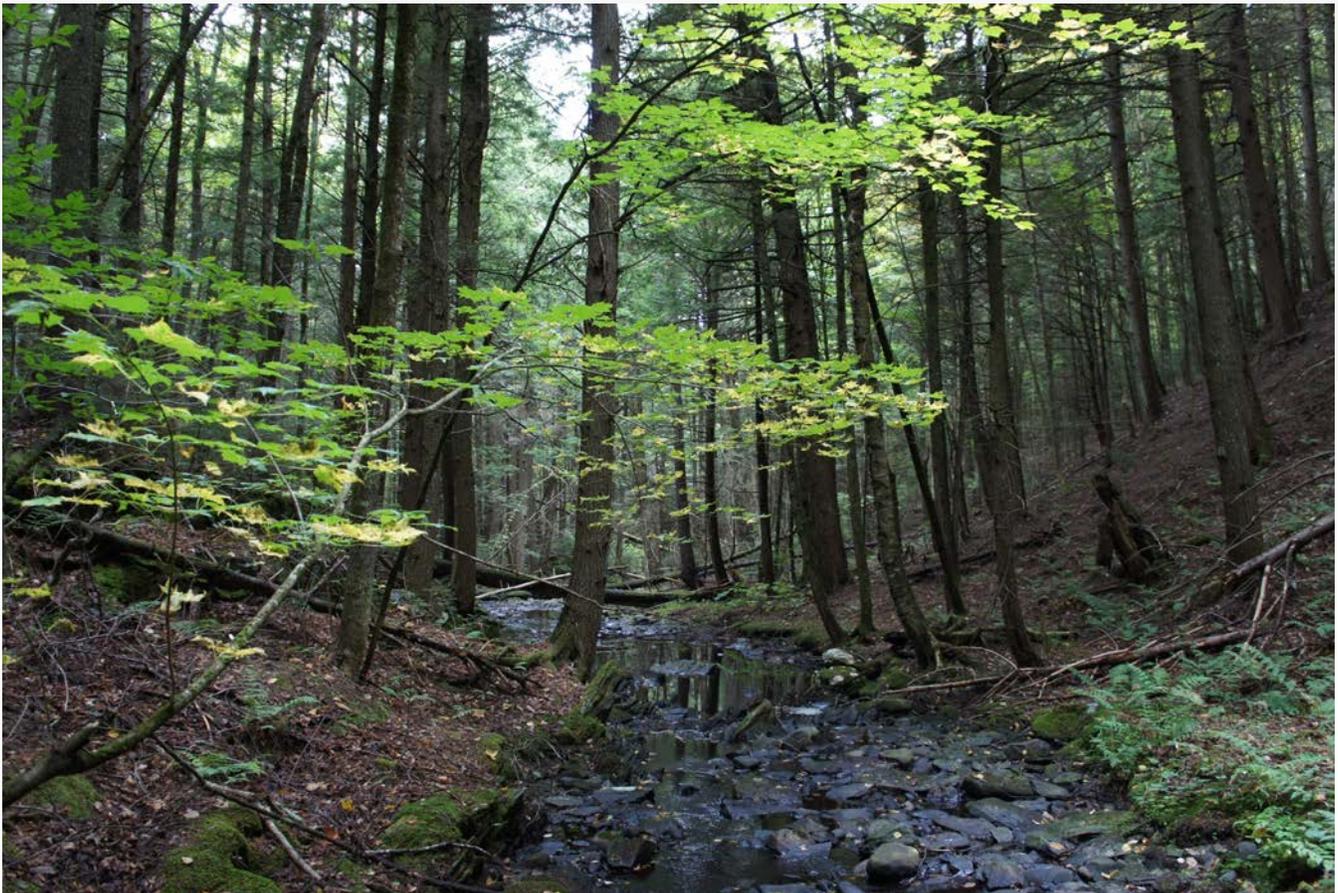


MOVING THE NEEDLE

A REVIEW OF NEEDS TO INCREASE CLIMATE ADAPTATION IN THE FORESTS OF NEW ENGLAND



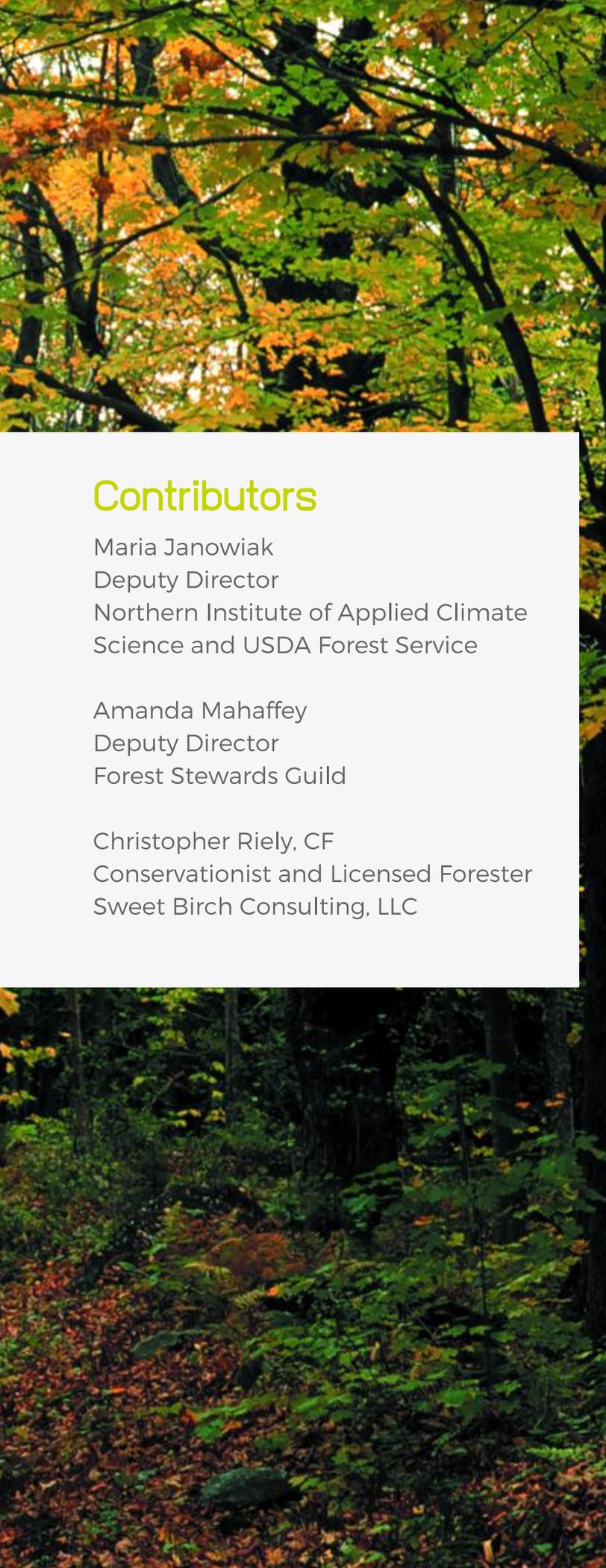


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Contributors

Maria Janowiak
Deputy Director
Northern Institute of Applied Climate
Science and USDA Forest Service

Amanda Mahaffey
Deputy Director
Forest Stewards Guild

Christopher Riely, CF
Conservationist and Licensed Forester
Sweet Birch Consulting, LLC

EXECUTIVE SUMMARY

Why

Forestry and natural resource professionals are increasingly looking for information on the anticipated effects of climate change on ecosystems, as well as management options for responding to these changes. The field of climate change adaptation has been growing rapidly in the past decade, with multiple organizations providing scientific and technical resources to help advance climate-informed practices across the northeastern United States and beyond. However, the inability to know exactly what will happen in the future can create a significant barrier to incorporating new information into management planning and practice.

Who

To help address this gap between science and implementation, the Forest Stewards Guild and Northern Institute of Applied Climate Science (NIACS) conducted a needs assessment among forest and land managers in New England to better understand the status of

climate change adaptation.

This assessment was designed to (a) characterize existing barriers to the implementation of climate-informed practices, and (b) identify actions that can help overcome the biggest challenges. This paper summarizes the results of the needs assessment. The intended outcome of this work is to inform the adaptation services that are provided by NIACS through the Climate Change Response Framework, the programming offered through the Forest Stewards Guild, and the work of other boundary-spanning organizations working in New England's forest climate adaptation community of practice.

What

The needs assessment consisted of an online questionnaire and four in-person listening sessions that engaged dozens of practitioners from across New England. Participants reported that more information was needed related to climate change and its interactions with other ecosystem components, particularly in



relation to tree species dynamics, wildlife, altered hydrologic cycles, invasive plants and pests, and human social and economic factors. Participants also pointed to a number of barriers to climate change adaptation. The greatest barrier identified was the perception of greater uncertainty of future conditions as a result of a changing climate. The challenges that were identified by New England practitioners as part of this assessment are consistent with

many surveys that have been conducted regionally and nationally among forest managers and natural resource professionals. It is important to note, however, that the participants described highly complex and nuanced challenges that demonstrated a high degree of understanding of climate changes issues that have not yet been documented in social science research among forest managers in the Northeast.

NEXT STEPS

A primary purpose of this needs assessment was to identify actions that would help overcome these barriers, and we explore five key themes in this report:

- Manage forests in the face of uncertainty.
- Expand information resources to inform decisions.
- Prioritize risks and management actions.
- Address barriers to sustainable forest management.
- Learn from each other through communities of practice.

The needs assessment process convened a large number of forest managers who are actively interested in advancing climate change adaptation in their work. By providing a venue for managers to express a desire for action, we have demonstrated that there is a high degree of interest in the topic and a timely opportunity to illuminate next steps for the forest climate adaptation community of practice coalescing in the region.



Providence Water is integrating adaptive management for changing climate conditions into its forestry program. This includes experimenting with planting both native tree species and those from farther south on a few sites.

Photo courtesy of Christopher Riely.



INTRODUCTION

The Earth's climate is changing in unprecedented ways, with the effects already being observed in the northeastern United States in the form of rising temperatures, extreme rainfall events, and sea-level rise (1). Ecosystems are changing in response to an altered climate, and more substantial impacts are anticipated in the coming decades (2,3). Forest and natural resource managers need scientifically credible, relevant, and timely information on climate change, its effects on ecosystems, and potential management options in order to effectively address the challenges brought about by a changing climate (4).

The amount of information available to forest and natural resource managers regarding climate change has grown rapidly over the past decade. An initial synthesis of climate change impacts for the Northeast region (5) was published in 2007, and a coalition of scientists produced a forest-based synthesis of the state-of-the-science for forest ecosystems in 2009 that is still largely applicable today (6-11). A large number of climate assessments and syntheses have been produced in the interim years to provide additional information at regional, ecoregional, and state levels (See <https://adaptationworkbook.org/resources> for a list).

Likewise, the body of knowledge regarding management responses for



climate change adaptation has also grown in the last decade, providing a array of processes and guidebooks to help facilitate the consideration of climate change in adaptation planning (4, 12, 13). Boundary-spanning organizations like the Northern Institute of Applied Climate Science (NIACS), the Northeast Climate Adaptation Science Center, and the national networks of the USDA Climate Hubs and US DOI Climate Adaptation Science Centers have developed additional resources by pursuing applied research, synthesizing scientific information, creating decision-support tools, and providing training and technical support to natural resource professionals. NIACS has led a Climate Change Response Framework (www.forestadaptation.org) project in New England and northern New York since 2014, supporting natural resource professionals in considering climate change in their management plans and activities (see box).



NEW ENGLAND AND NORTHERN NEW YORK CLIMATE CHANGE RESPONSE FRAMEWORK

NIACS initiated the Climate Change Response Framework (CCRF) to deliver credible and relevant information to land owners and natural resource managers regarding climate change and its effects on forest ecosystems (4). After developing the approach in the Midwest, a CCRF project was launched for New England and northern New York in late 2014 and has since provided diverse resources and trainings to support natural resource professionals in addressing climate change issues. Over five years, the CCRF has worked to create:

- **Partnerships:** The CCRF brings organizations together to increase their collective capacity to cope with the overwhelming nature of climate change. These partnerships ensure relevance, credibility, and usefulness of CCRF activities and products.
- **Vulnerability Assessments:** A vulnerability assessment was created for this region to describe climate change risks and opportunities for forests. Two global climate models, three forest impact models, hundreds of scientific papers, and forest manager expertise were combined to assess the effects of climate change on forest ecosystems.
- **Adaptation Resources:** The CCRF provides a growing set of adaptation resources, including an adaptation workbook and topical compilations of adaptation strategies, to help land managers and landowners devise adaptation actions to meet their objectives. Workshops and trainings provide additional support in using new tools.
- **Adaptation Demonstrations:** The CCRF shares the stories of adaptation demonstrations, which are real-world examples of how land managers have considered ecosystem vulnerabilities and adaptation strategies in choosing actions to meet their management objectives.

This needs assessment will help inform the development of CCRF resources to address land managers' needs over the next several years.



Mass Audubon is demonstrating best forest management practices for songbird conservation and climate change on the 1,100-acre Elm Hill Wildlife Sanctuary in central Massachusetts.

Photo courtesy of Tom Lautzenheiser



Universities and non-governmental organizations are also engaging in creating synthesis and communication products. For example, Manomet convenes the Climate Smart Land Network, which increases the accessibility of climate change science to forest landowners and managers across the country, with strong representation from organizations in New England (www.climatesmartnetwork.org). The University of Maine's Center for Research on Sustainable Forests is leading a Forest Climate Change Initiative to provide resources and increase networking in regard to climate change and forest ecosystems (www.crsf.umaine.edu/forest-climate-change-initiative), and the University of Massachusetts Amherst is coordinating the Massachusetts Ecosystem Climate Adaptation Network – a community of practice for climate adaptation practitioners and researchers who are interested in ecosystem resilience and natural resources conservation (www.massecan.org). Professional meetings held in New England, such as those hosted by the Society of American Foresters and Forest Stewards Guild, routinely focus on or include presentations related to climate change impacts and forest adaptation.

These resources have undoubtedly helped “move the needle” on forest climate adaptation, and yet questions still remain. How much has the metaphorical needle moved? What is needed to move it further? To better understand to the status of climate change adaptation in New England, staff from the Forest Stewards Guild and NIACS engaged with forest and natural resource managers from the Northeast to explore their perceptions of what is currently known and unknown regarding climate change and forest adaptation. Our goal was to elicit, identify, and synthesize the major needs among natural resource practitioners who are working in forests. We hope that this work will promote scientific research, communication, and other activities that address and overcome the greatest obstacles in responding to climate change and interacting forest stressors. By addressing needs voiced by the forestry community, we hope to enhance climate adaptation efforts in the forests of New England.

Our goal was to elicit, identify, and synthesize the major needs among natural resource practitioners who are working in forests.



NEEDS ASSESSMENT PURPOSE AND PROCESS



This managed forest in Vermont demonstrates the alignment of managing forests with birds and climate adaptation in mind (left). Gypsy moth and other factors threaten the resiliency of this oak forest in Connecticut (right). Photos courtesy of Amanda Mahaffey.

During fall and winter of 2018-2019, we undertook a needs assessment of forestry and natural resource professionals in New England to better understand their perceptions and interest in themes related to forest adaptation and climate change. This project was also intended to inform future work by the Forest Stewards Guild, NIACS, and partner organizations working in this arena. This effort was focused on listening, community-building, and action, not on the production of a rigorous social science research paper. We sought qualitative, nuanced information more than quantitative results. While the assessment was initially intended to be used internally to guide organizational programming, there was a large degree of interest from participants in seeing how their input was used and knowing what came out of the work that they put into it. This white paper summarizes recurring themes that participants expressed

during this process.

Two components generated input to this needs assessment: an online questionnaire and in-person listening session events. The online questionnaire included about ten open-ended questions and was available from October 8, 2018 to May 24, 2019 (Figure 1, Appendix 1). Information about the questionnaire was distributed to managers through a variety of email distribution lists (e.g., the Forest Stewards Guild and NIACS Climate Change Response Framework email newsletters) with an intended focus on reaching professionals in New England and New York State. Responses to the questionnaire are informative, but are not expected to be representative of the entire community of forest and natural resource professionals in the region because of the informal and non-systematic nature of the request.



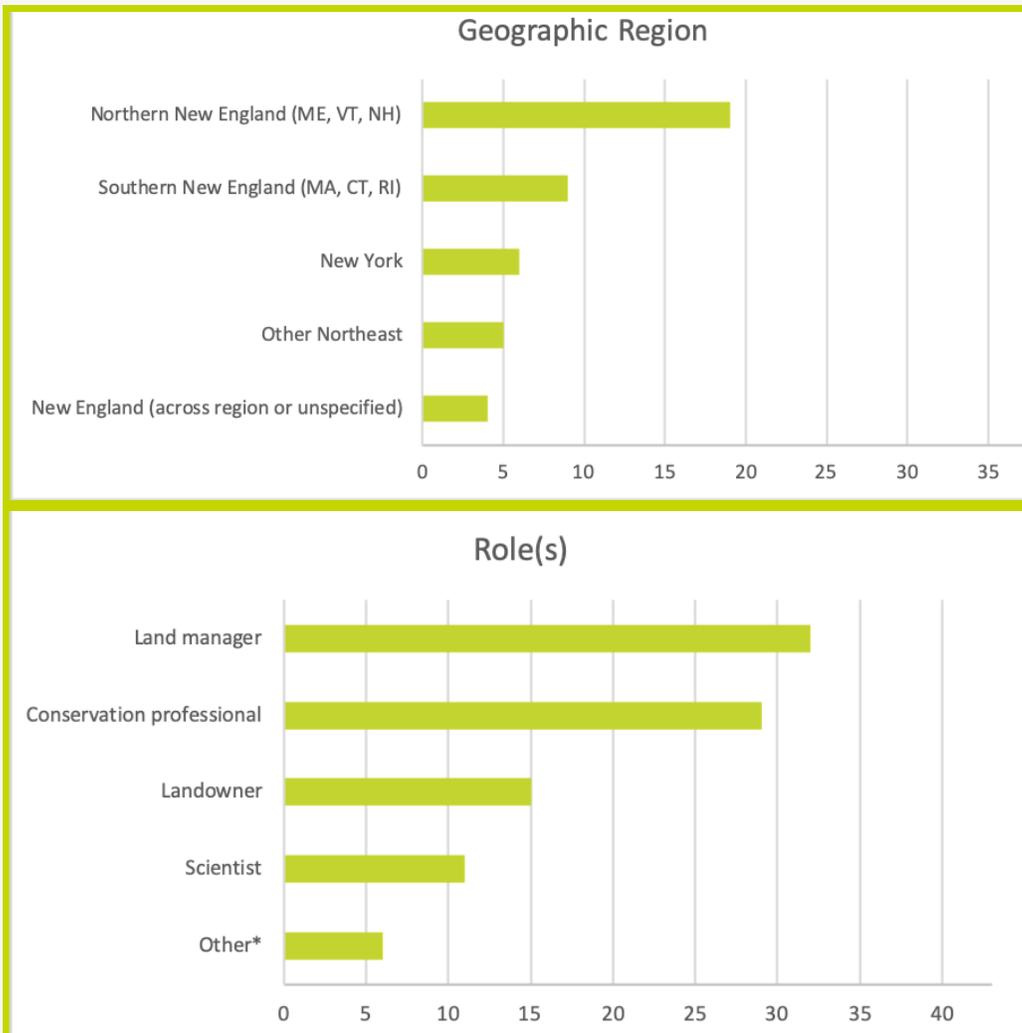


Figure 1. Description of online questionnaire responses from 43 individuals in the Northeast U.S.

Left: Geographic area in which the respondent works. (Q: In what geographic area do you work?) Right: Role(s) that the respondent identifies with (Q: Do you consider yourself to be... [check all that apply]?). Five responses from individuals working in areas outside of the Northeast U.S. are not included.

*Examples of “other” include: forester, forest technician, logger, and extension professional.



Dr. Tony D'Amato outlines silvicultural considerations for managing ash in the context of the emerald ash borer. Photo courtesy of Amanda Mahaffey

Additionally, four listening sessions were held across New England during November and December 2018. Local managers were invited to participate in sessions and help “identify what foresters and natural resource professionals need—whether that be scientific information, tools, or other resources—to increase our ability to help forests adapt to changing conditions.” Three of the sessions were three hours long and began with an introduction to the session in which individuals were asked to share their name.



position/organization, and one observation of how local forests are or may be changing in response to a changing climate (see agenda in Appendix 2). These introductory responses were synthesized on a flip chart. Next, a 30-minute presentation provided a “30,000-foot view” of climate change effects on forests and tools for managers. This transitioned into a discussion session in which two facilitators asked participants questions intended to elicit responses related to the core topic (e.g., What do we most want to know about this

element of climate change? What would help move the needle on forest adaptation?). Larger groups were divided into topical breakouts to encourage more focused discussion. A fourth listening session was hosted within the Forest Ecosystem Monitoring Cooperative’s Annual Conference, which had a climate change focus in 2018; this listening session was abbreviated to 90 minutes to fit into the format of the larger conference format and focused on discussion among participants.

Table 1. Description of listening sessions held during November-December 2018.

Session	Northampton, MA	Orono, ME	Smithfield, RI	Burlington, VT
Length/Format	3 hours with overview presentation and discussion	3 hours with overview presentation and discussion	3 hours with overview presentation and discussion	90 minutes of discussion within a larger conference
Approx. no. of participants	4 (inclement weather)	27	20	30
Core question(s)	What information, tool, or resource is most needed to move the forestry community ahead on adaptation? <ul style="list-style-type: none"> • What do we know? • What don't we know? • What would we most like to know? • What resources are available? • What would be most valuable to help “move the needle” in advancing adaptation? 			
Breakout topics	none	<ul style="list-style-type: none"> • Wildlife • Tree species • Hydrology (water/drought) • Invasives • Social and economic implications (determined by participants) 	<ul style="list-style-type: none"> • Tree species • Hydrologic dynamics • Invasives • Communication • Understory response (determined by participants) 	<ul style="list-style-type: none"> • Tree species • Invasives • Wildlife • Species (non-tree, non-wildlife) • Water • Human community (proposed by facilitators and modified by participants)



HOW ARE PEOPLE IN THE FORESTRY COMMUNITY THINKING ABOUT CLIMATE CHANGE AND FORESTS?

As the evidence for human-caused climate change continues to grow and as forests are increasingly threatened by extreme weather and altered climate, the field of climate change adaptation is rapidly expanding. In the past decade alone, several collaborations have been developed to help make climate-related research more accessible to management audiences. With the growth of climate change adaptation as an active area of interest among both scientists and land managers, it is likely that forester and land manager perceptions are also changing rapidly.



What the Research Says: Perceptions Are Barriers

Several studies conducted around the United States and Canada provide context for how land managers are thinking about climate change in their work and inform programs aimed at this audience. Notably, several new research studies are now underway within New England that will provide a better understanding of how foresters and other land managers are thinking about climate change.

Nationally, the Yale Program on Climate Change Communication (14) has been tracking the perception of the U.S. public on climate change issues for the past decade. Products like the Yale Climate Opinion Maps explore differences in public opinion on global warming, showing that about 70% of the American public believes that global warming is happening and about 57% of the public believes that it is caused mostly by human activities (15, 16). Perceptions differ across geographic regions as a function of demographic, cultural, and ideological factors (13, 14).

There are a handful of studies that have been conducted over the past decade regarding the perceptions of foresters and natural resource professionals. The fact that these studies have been conducted at different times, in different geographies, and with different questions means that it can be hard to generalize what natural resource



professionals are thinking in regard to climate change, but similarities across studies can suggest larger patterns. Studies of foresters and other natural resource managers generally point to an acceptance that global warming (or climate change) is occurring (17-19). However, similar to the American public, not all of these individuals attribute changes to human causes (17-19). Across several regions, scientists have found that multiple factors influence how foresters perceive climate change, such as their position within the sector (e.g., academia, government, private, industry), years of employment, and political views (19-21).

These perceptions can influence how climate change information is integrated into foresters' work. For example, a survey of more than one thousand forest managers and researchers indicated that the majority of managers are confident that climate change is occurring, but that confidence decreases when it comes to identifying and implementing management actions for mitigation and adaptation (17). However, in regard to adaptation practices, foresters indicated that they were willing to implement some actions such as forest thinning, prescribed burning, increasing landscape connectivity, and detecting and eradicating invasive species. Additionally, foresters indicated they were willing to learn more about other practices such as creating local refugia or assisting the introduction of non-native species expected to be better adapted to future conditions. Actions that have been tested over decades had greater support than more novel approaches (17).

A more recent study used interviews with 119 managers from New England to understand how climate change is affecting management motivations and practices (22). The vast majority of managers identified several reasons for incorporating climate change into management (e.g. maintain natural regeneration, client demand) and actions they were taking (e.g. managing for natural regeneration, managing for riparian health). Uncertainty was identified as a major barrier from about 60% of the New England respondents, followed by limitations of clients (e.g. affordability, awareness, perceptions) (22).

WHAT WE HEARD: OBSERVATIONS OF FOREST CHANGE

Climate change is causing or exacerbating a wide variety of changes in forest ecosystems. This is evidenced by abundant scientific research (2, 6-11, 23, 24) within the region, and perhaps more importantly, by observations of change from land managers, landowners, and others in the region. Observations reported via the questionnaire (Figure 2) and in the listening sessions were similar in that they: 1. showed a diverse array of changes, and 2. reflected local variability in tree species composition, forest history and interacting non-climate stressors. For example, participants in the Orono listening session specifically mentioned local observations such as changes in coastal spruce forests and the timing of the moose rut.



Likewise, in the listening sessions, forest managers and scientists were asked to identify “what we know” regarding how climate change affects forests and to then highlight areas of greater certainty. Several themes surfaced across the above topics in multiple sessions:

- **Climate change impacts are being observed regionally.** Across both the questionnaire and the listening sessions, managers pointed to a wide array of forest changes that are currently being mediated by climate change or are expected to have interactions with an altered climate in the future (Figure 2). Many were familiar with regional climate change assessments and research studies that provide evidence to support their observations of change.
- **Many forest stressors are increasing,** including stressors indirectly related to changes in climate. Managers also pointed to several current forest stressors that are causing significant management problems such as invasive plants, introduced forest pests, and deer herbivory. These challenges often feel insurmountable, and climate change adds additional and often unknown complexity and stress to systems that are already under pressure.
- **Forests have responded to past change.** Many people pointed to the long legacy of human disturbance and recovery in northeastern forests over the past 300+ years. The fact that forests are still abundant across New England provided evidence of resilience in natural ecosystems and seemed to serve as a source of optimism.
- **Individual tree species will respond in unique ways.** Foresters pointed to the unique characteristics of different tree species and their relationship to one another as fundamental traits resistant to change. There were calls for refocusing and relearning “basic” information regarding tree silvics as a way to understand how the individual parts of ecosystems may change.
- **Ecosystems are complex!** Discussions of climate change highlighted the inherent complexity of ecosystems and the challenges of working within such ecosystems to meet human needs.

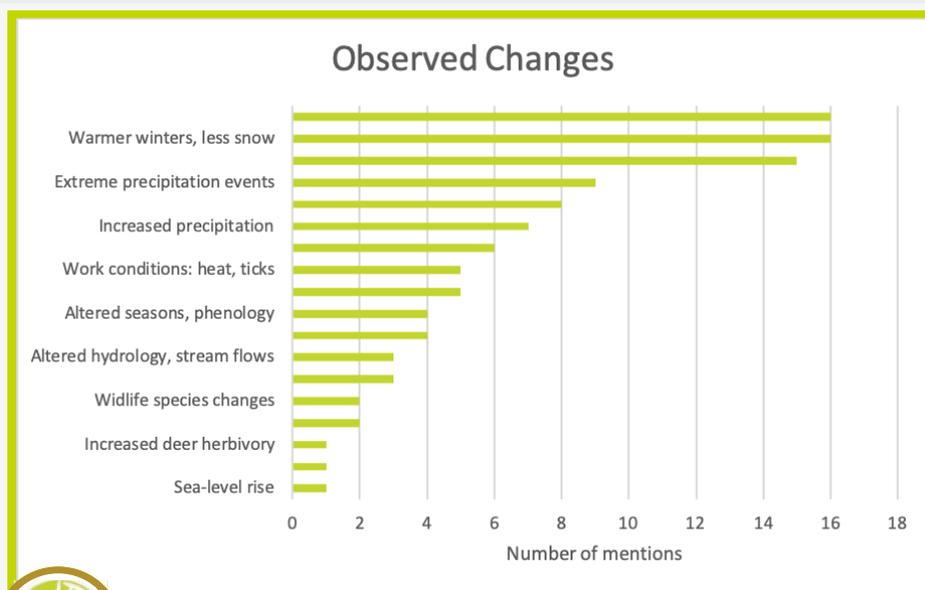


Figure 2. Summarized distribution of climate change observations for the region based on responses to the open-ended question, “What changes are you seeing on the ground that might be related to climate change?” (Q3).



INFORMATION NEEDS

Listening session participants identified some ways that climate change is already affecting forest management, as well as many potential future impacts. The topics identified during individual sessions aligned remarkably well among the different sub-regions of New England, with geography influencing which issues were most salient (Table 1). Participants expressed concern about forest climate adaptation needs in the areas of tree species dynamics, wildlife impacts, hydrologic alteration, invasives, and human social and economic factors. The concerns expressed by questionnaire respondents similarly fit into these broader topics. A summary of research needs is presented in Appendix 3, and full notes from the listening sessions are available upon request.

Tree Species Dynamics

Many participants expressed concerns over how different tree species, their customary forest structures, and natural forest ecosystem processes would respond to the changing climate. In southern New England, concerns were raised over oak species, which are threatened by deer herbivory, gypsy moth, and a complex set of factors that inhibit regeneration. In northern New England, participants identified a need for a better understanding of the influence of climate change on genetic diversity over time and across the landscape, species response to freeze-thaw cycles and changing disturbance regimes, and

the effects of management decisions at the landscape scale. Participants called for a better synthesis and sharing of available information, as well as an integrated monitoring network.

Wildlife Impacts

Participants in the needs assessment have observed changes in wildlife dynamics as a result of the changing climate, such as: shifts in wildlife population abundance and distribution; changes in seasonal weather patterns (e.g. snow cover and depth) leading to expanded disease vectors; and reductions in aquatic and landscape connectivity driven by an increasingly fragmented landscape. We heard a desire for research that details the subtleties of these intertwined dynamics among climate, habitat (vegetation), and wildlife species. How will wildlife species adapt to new conditions, including changing seasons and more widespread disease? What watershed management practices might favor cold-water fisheries? How will impacts to pollinators affect other parts of the ecosystem? What about keystone species and iconic species? What role will climate refugia play? Above all, participants expressed a need for information on how to make site management decisions in the absence of complete information on these complex dynamics.



Hydrologic Alteration

Climate impacts on hydrology were a recurring theme in the listening sessions and questionnaire. How will climate change affect the public water supply and water quality in New England? Do we need to adjust forestry Best Management Practices to accommodate altered precipitation patterns? Participants expressed a desire for tools to help estimate streamflow and sedimentation impacts over time, and to prioritize potential high-impact watershed areas. Drought was a major concern. How will changes to soil moisture dynamics affect soil fertility and seed viability? Will forest pathogens increasingly gain ground in a wetter climate? What silviculture is appropriate for these changing conditions in soil, water table, and other microclimatic factors?

Invasive Plants and Pests

A large number of managers, both through the questionnaire and the listening sessions, identified that invasive plants are currently a major management challenge and one of the biggest threats to forest health. Climate change was generally viewed as an interacting stressor that would exacerbate current efforts to battle invasive plants. Forest pests and pathogens were also identified as a concern. The overriding question from participants was what to do about it. Small groups discussing invasive species identified a desire to create social change that would support invasive species management.

Participants also articulated a need for information about forest management practices that can mitigate invasive plant and animal species.



Human Social and Economic Factors

While this project initially sought input on forest science research needs, we kept the door open to other ideas. Consistently, human social, community, policy, and economic factors were mentioned as essential barriers to address in order to adapt forests to the changing climate. In a region where 84% of the forest land is privately owned (2), woodland owners' values have a large influence on what climate adaptation actions can be taken on the ground. Communication with this audience about forest climate adaptation must be effective in order to move the metaphorical needle. Changing climate conditions affect the ability to harvest timber and fuel the forest products industry. Participants expressed that politicians and decision-makers need to gain a better understanding of (and provide public support for) policies and programs to advance climate adaptation in forests. Education, hope, money, and a land ethic were identified as clear needs to drive change.

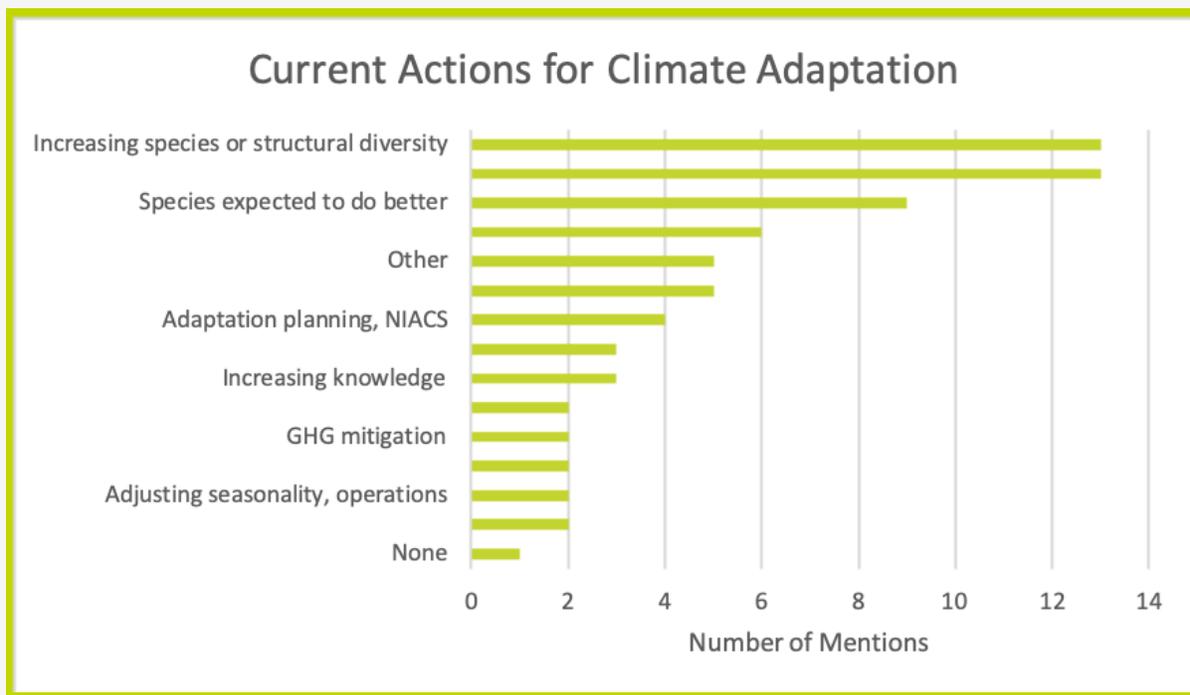


ADAPTATION ACTIONS

All of the above observations informed the discussions of what can be done to adapt forests to the changing climate and provided a note of hope that the forestry community can collectively move the needle on forest climate adaptation. We heard from managers that many are already taking action to enhance the ability of forests to cope with a wide range of changing conditions, which is consistent with other research done in the region (22). Among the self-selected respondents to the online questionnaire, nearly all were able to point to specific actions that they are currently using to help forests adapt (Q6: What actions are you currently taking to adapt your forests?).

More than one-quarter of respondents talked about current actions that they were taking to promote overall forest health and resilience as a way of helping ensure that forests would be able to adapt. Managing for overall species and structural diversity was another action that was identified as supporting adaptation by providing future options for the forest to adapt. For example, one respondent said self-reported as currently “Practicing good hardwood silviculture focused on establishing new age classes and maintaining native diversity to the greatest degree possible”, and “Attempting to fight invasive plant species [to help forests adapt to changing conditions].”

Figure 3. Summarized distribution of climate change observations for the region based on responses to the question “What actions are you currently taking to adapt your forests?” (Q6).



Several respondents also discussed promoting tree species that are expected to fare well under future conditions. This included working with the current forest composition to promote species that are currently present in forests (“Leaning on species that can do well no matter what climate does...”) and shifting forest composition (“Transitioning to oak/pine where appropriate.”). A few respondents mentioned efforts to plant trees (“limited planting of “winners” where appropriate”).

Some respondents said that they were actively seeking out new information to better understand the climate change impacts and potential management responses. This included self-education (reading papers, etc.) and attending trainings offered by NIACS and other organizations.

In looking forward (Q8: What additional actions should be taken (by you or others) to help forests adapt to a changing climate?), respondents often pointed to steps that would increase the boots-on-the-ground efforts described above. For example, several people pointed to the need to reduce invasive plants or other stressors, proactively work to improve stream crossing infrastructure, or plant future-adapted trees. Many broader actions were also identified, such as the need to accelerate the pace of land conservation and ensure connected landscapes. Numerous responses also pointed to diminishing the causes of climate change by reducing forest land conversion and

use of fossil fuel energy and petroleum products (plastics).

In sum, participants in this needs assessment are taking action, but identified still greater needs and barriers to further action.



BARRIERS TO ADAPTATION

Tackling climate change will require overcoming the many barriers that are created or amplified by this complex issue. As mentioned above, a primary purpose of the needs assessment was to better understand the barriers, both real and perceived, that managers experience when trying to promote climate change adaptation in forest management. We asked questions about barriers that managers encounter in the questionnaire (Table 2) and during the listening sessions.



Many of the barriers that were identified through this needs assessment have similarities to barriers identified in previous adaptation efforts. For example, the Climate Change Response Framework was developed in a way to address major management barriers (4) identified by managers:

- **Feelings of overwhelm from the size and complexity of the issue**—addressed through partnerships to increase organizational capacity and promote shared learning
- **A lack of information at scales relevant to management** – addressed through vulnerability assessments, science syntheses, and trainings to ensure science is accessible
- **Desire for customized management recommendations** – addressed through a set of adaptation resources and trainings that allow managers to integrate climate change into their work
- **A need for real-world examples to demonstrate adaptation in action** – addressed through a network of more than 350 demonstration projects, with more than 100 in New England.



Recent research also points to uncertainty as being the greatest barrier to managing for climate change reported by forest managers in New England (22). Although some may argue that the persistence of uncertainty as a major barrier to adaptation suggests that boundary-spanning organizations have not been able to address key manager needs for information, (22) the reality is that uncertainty is an inherent and immutable characteristic of climate change (25-27). Rather than reduce uncertainty, the challenge is to let go of expectations of stationarity and adopt new skills in planning and acting during uncertain change (4, 28-30).

In short, managers increasingly need to manage in the face of uncertainty.

Forest managers also identified several barriers that are not primarily driven by climate change but can stymie adaptation efforts. These include a lack of funding or resources to complete work, lack of access to forest products markets, resistance to active forest management, short-term thinking by landowners, and immediate stressors like deer herbivory and invasive species. These issues often need to be addressed before climate change adaptation can become part of the management discussion.



While perhaps not a direct barrier, it is also important to point out that there may be significant lag times between when information may be first available and when it is used in the implementation of adaptation activities. It takes time to move through the process where scientific information is produced, communicated to managers, and ultimately acted upon, and this process can take even more time given the inherent complexity and uncertainty of

climate change. Climate change is still a relatively new topic within natural resource management, and climate change adaptation is still emerging as a new discipline. Where managers identified a lack of information, resources, or recommendations as a barrier to management, it is important to consider whether that information does exist. The issue could be a lack of information, or it could simply be a delay in how the information is being transmitted and acted upon.

Table 2. Themes observed among responses and example quotes in response to the question “What barriers do you see to helping people adapt forests to the changing climate?” (Q7)

Type of barrier	Example quotes
Uncertainty about what to do	“too many unknowns” “lack of knowledge of what’s coming—and what might be coming and when” “uncertainty in future changes and rates of changes”
Feeling overwhelmed	“feeling that nothing can be done” “Uncertainty and massive scope of changes and impacts can lead to inaction from practitioners.”
Scientific information is inaccessible	“The academics cannot translate the information to on the ground practitioners...” “... The biggest challenge is that regular folks don’t understand the language of scientists. We need to help locals understand what scientists are talking about.”
Lack of funding or resources to implement work	“Cost of taking action. Lack of clarity about long-term cost-benefit of actions taken now” “Information and finances” “Funding...”
Disbelief in climate change – among the public, decision-makers, landowners, etc.	“Acceptance that anything is even happening, and if the effects of the change can be mitigated.” “Denial of the climate changes already in place. A blindness to the likelihood of effects of not adapting. ...” “Inability to imagine how bad things might get.”
Decisions made with short-term thinking	“Encouraging landowners to think with a more long-term mindset when it comes to land management.” “The scale of private land seems like a challenge to adaptation. I mean time scale as well as spatial scale. Private land tends to change hands regularly making long term planning more challenging. Smaller woodlots have limited options for adaptive management” “education, short land tenure”
Traditional barriers to forest management	“only a small percentage of landowners actively manage” “general apprehension re: management to begin with” “Markets are non-existent to take low-grade materials. DEER EAT every seedling except exotics.”
Lag times to implementing adaptation	“I think people and organizational structures are often the biggest barrier in helping forests adapt to the changing climate. Change is difficult and can be slow, especially for large organizations and government.” “As a technician, all I can do is discuss the topic. It’s the licensed foresters or the landowners who decide how, or even if, to adapt the forests.”



HOW CAN THE FORESTRY COMMUNITY MOVE FORWARD ON CLIMATE CHANGE ADAPTATION?

Conversations about what may be known or understood led to discussion about what is not understood (see summary of identified research needs in Appendix 4) and how to move beyond the current state of affairs. The following sections summarize major themes on how to move forward on climate change adaptation.

1. Manage in the face of uncertainty

Uncertainty has been identified as the foremost barrier to managing climate change among forest managers in New England (22, 30). In many ways, this is not surprising given that climate change pushes ecosystems in new directions that are different than the perceived stationarity of the past (i.e. forests are no longer believed to be closed systems with predictable dynamics). Climate change adds complexity and stochasticity to already complex ecological and social systems.

Managers have many questions about climate change and have voiced a desire for a more complete understanding of what will happen.

Questions that were expressed during the listening sessions touched on various specific focal points and acknowledged the interactions among different components of natural systems:

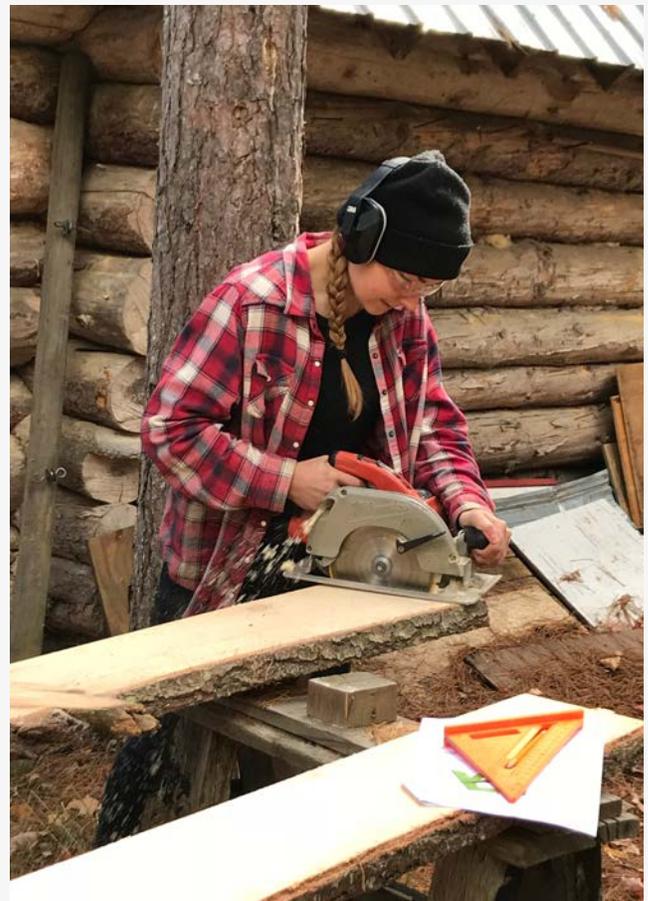
- When will changes occur?
- Where will changes be most severe?
- What are the combined effects from interactions among stressors, disturbances, and management?
- Which species (not just tree species) are most vulnerable?
- What other stressors are coming our way?
- What are significant thresholds for change?
- Ecosystems are complex – how will climate change affect all of the pieces individually and in total?

These questions suggest that the forestry community could benefit from tools for facing uncertainty and acting in the absence of complete knowledge. Acknowledging this inherent uncertainty may help give individuals license to propose plans and act in the face of unknowns. Participants provided numerous specific ideas about what information would be most helpful to them (see Appendix 3), but limited resources mean that it is not practical or viable to try to answer all questions before making a decision. The reality is that decisions will need to be made without “key” information. Waiting for more information can have implications for forest ecosystems because taking no action is still a management decision that will have



on-the-ground impacts. Foresters' reluctance to act without complete information may reflect the long-term nature of the profession, an environmental ethic and culture that emphasizes risk reduction rather than risk-taking, and personality characteristics of people who are often drawn to the field.

Adaptive management is often suggested as a means to work with incomplete information and “learn by doing” (28, 31, 32). Several processes for climate change adaptation exist that incorporate adaptive management principles, (4, 12, 33) including the Adaptation Workbook developed by NIACS as part of the CCRF process (www.adaptationworkbook.org). The Adaptation Workbook has been used by hundreds of forest and natural resource managers in New England to help overcome some of the inertia caused by feelings of uncertainty that are inherent to discussions of climate change. Processes like the Adaptation Workbook that support adaptive management do not reduce the uncertainty associated with climate change, but provide a framework for identifying and evaluating risks in order to move forward with incomplete information.



Providence public high school students helped carry out an enrichment planting of both native tree species and others projected to be adapted to future climate conditions on a field trip to the Scituate Reservoir watershed lands (left). A future forester builds a Leopold bench from a tree harvested from a stand managed for the long term (right).



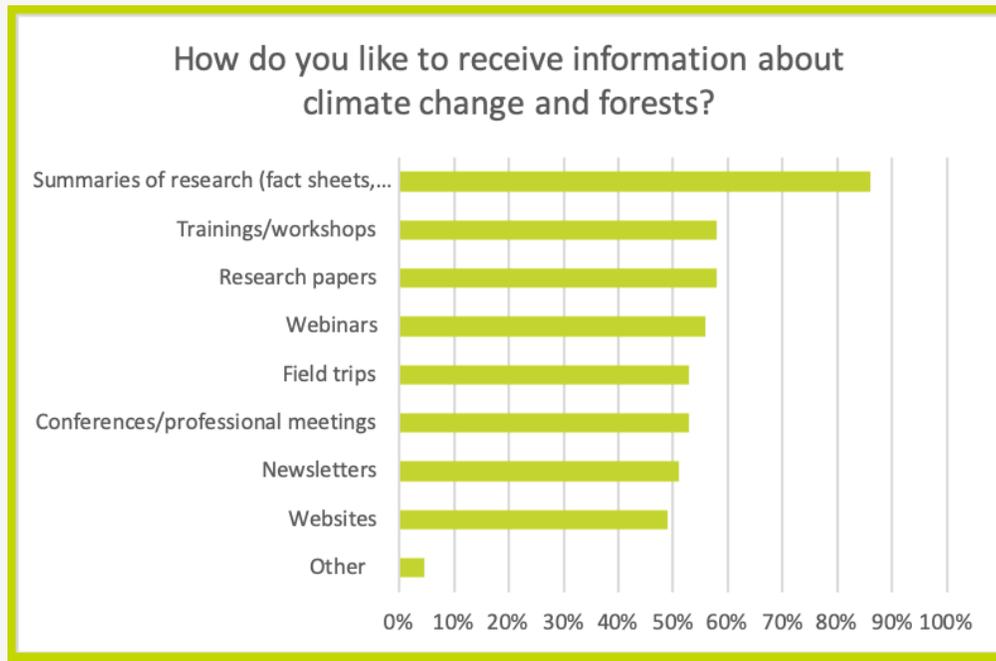
2. Expand information resources to inform decisions

The survey and listening sessions demonstrated that forest managers and landowners need more information and resources to incorporate forest adaptation into their work.

- **More specific information.** The suggestions from managers, detailed above in the Information Needs section, generally build on existing, available scientific information, but raise specific questions on how climate change will affect local natural ecosystems and human communities. For example, there has been a great deal of research in the past five years regarding regional changes in hydrologic cycles, both extreme precipitation and drought, (34-37) yet managers requested more specific information products to better understand impacts at the stand scale as well as potential management interventions for protecting water supply and quality.
- **Finer spatial resolution.** Many of the vulnerability assessments and information resources that are currently available for forest managers generally provide information at coarse scales, while other guides (such as the Adaptation Workbook and adaptation menus developed by NIACS) intentionally avoid making site-specific recommendations. Managers expressed a desire for information at finer spatial and temporal resolutions, such as guides with a focus on specific geographic regions or time horizons.
- **Tools for overcoming uncertainty.** Assessments, tools, and datasets are still considered valuable, but feedback indicated a need to go beyond traditional scientific approaches to inform decisions. Given issues of uncertainty discussed above, specific information that is able to help pinpoint and reduce uncertainty will be highly valued.
- **Social and economic tools.** Acknowledging that existing resources are most highly developed in the natural sciences, participants also expressed a desire to also incorporate social and economic components into tools and programming. For example, managers who attended the workshop in Maine suggested two specific products which they believed would be valuable: 1. an assessment of the economic impacts of climate change on the forests of New England and 2. a regional map or GIS database illustrating the spatial distribution of socio-economic impacts.
- **Science I can use.** Participants identified that current forms of technology transfer are generally popular (Figure 4). Although some managers identified scientific information as being inaccessible (see comments in Table 2), research summaries and even research papers were identified as being some of the most useful sources of information. To some extent, this appears to reflect a difference in what information land managers use to educate themselves versus information that they provide to landowners or members of the public.
- **Tools for communicating with the public.** Participants expressed a need for communication tools to help New England's private landowners make climate-smart decisions, as well as strategies for communicating with other members of the public. More resources may be needed to help managers communicate climate risks and forest adaptation responses for climate change to non-professionals.



Figure 4. Preferred methods of information delivery (Q10: How do you like to receive information about climate change and forests? [Select top ~5])



3. Prioritize risks and management actions

Climate change is a global issue that will affect all parts of the landscape in varying ways. Forest managers expressed a desire to be able to prioritize climate-related risks in order to identify which issues and geographic areas to address first. Identifying the most serious risks would help land managers focus on potential management approaches and specific actions that are likely to address the most significant impacts and improve resiliency. Ideally, a geographic approach to risk prioritization could be applied at the scale of forest landscapes down to individual properties to help identify locations that may be particularly vulnerable to climate change impacts and to identify areas of potential refugia.

The Nature Conservancy’s Northeast Resilience Project (38, 39) and its related mapping tools provide one example of information resources that are available to help identify and prioritize places that are expected to be more resilient because they support higher biodiversity. Likewise, vulnerability assessments point to factors that put ecosystems at greatest risk from climate change. Land managers can use these tools together to evaluate risk at finer spatial scales and consider opportunities for targeted management interventions.

Managers suggested that climate adaptation may be a promising opportunity for the forestry community to develop recommendations for best practices and a library of informative examples. While each place and situation is unique, climate change presents many common risks and



threats that are shared within a landscape, allowing for cross-ownership opportunities to respond with coordinated adaptation actions. Landowners and managers working in the same forest types and ecosystems and with similar management objectives are likely to have shared challenges and concerns. Some of these similarities are beginning to become evident through the 100+ adaptation projects that have been developed across the region to date (www.forestadaptation.org/demos). As forest adaptation principles become more clearly defined through research and adaptive management, effective adaptation practices can be synthesized and shared to promote more widespread use. This shared learning on risk prioritization could help speed decisions and actions toward forest adaptation.

Managers pointed to the development of voluntary Best Management Practices (BMPs) for water quality protection as a potential model for selecting appropriate climate adaptation actions. BMPs were developed in response to a need to improve techniques for protecting water quality while carrying out forest management operations. Some of these practices were not widely implemented when first introduced, but have since become standard in the United States. Water quality BMP specifics vary among states and regions, reflecting the characteristics of different ecosystems, but they all follow the same overarching principles. Water quality BMPs themselves could potentially be enhanced with

consideration for climate change. Analogous forest “climate adaptation BMPs” might someday garner public acceptance and use without being regulatory.

4. Address barriers to sustainable forest management

The great majority of foresters work for organizations and landowners where climate adaptation has yet to be fully integrated into strategic and operational planning. An important component of advancing forest climate adaptation is gaining a better understanding of constraints and limitations that currently exist. Many forestry professionals are trained to focus on applied science and operational challenges, but geographic, organizational, and cultural impediments are just as significant and can prove to be more challenging barriers. In many situations, the capacity to adapt may be limited by the capacity to implement any form of forest management.



Kevin Evans points out forestry features at the Dartmouth Second College Land Grant, a site for long-term climate adaptation research.

Photo courtesy of Amanda Mahaffey



Regional issues posing obstacles emerged as an important thread in each of the listening sessions. In Maine, participants spoke about the large role that the forest industry has played in shaping management in northern New England. As the industry undergoes structural changes, managers must adapt to changing markets that affect how they can implement forestry activities. In contrast, participants in densely populated southern New England described the challenges of practicing forestry on small land parcels. Making the case for including climate resiliency and adaptation among management considerations for small properties can seem particularly difficult, or at least requires a different approach from that applied to large forest ownerships or landscapes.

An important component of advancing forest climate adaptation is gaining a better understanding of constraints and limitations that currently exist.

Managers spoke about mixed public social perceptions of forestry and confusion about the role of active management related to climate change, roundly agreeing that greater acceptance is needed to gain traction. There was much discussion of improving communication strategies and messages, and a few solutions were offered. Some individuals

suggested using communication messages that more directly compare the costs of potential adaptation actions with the possible costs (and risks) of no action. In addition to clarifying communications, one promising strategy that emerged across multiple sessions was to identify easily-understood actions that have the greatest chances of both succeeding on the ground and in gaining social acceptance. From this short list, the forestry community could then develop and promote “no-regrets” actions to focus on and rally around.

Work being done in the “MassConn Woods” region of northeastern Connecticut and south-central Massachusetts provides an example of incorporating climate change information in forest management activities on small woodlots. Several organizations, including the New England Forestry Foundation, American Forest Foundation, and NIACS, worked together to create a comprehensive program for engaging foresters and woodland owners in conversations about climate resiliency and adaptation. Climate change research was synthesized into handouts for foresters and woodland owners and foresters were given additional training on climate change impacts, forest management responses, and communicating with landowners. Through projects funded by the Wildlife Conservation Society and the USDA Forest Service, a network of trained consulting foresters visited private lands to develop climate-informed management plans.



5. Learn from each other through communities of practice

Climate adaptation presents land managers and owners with an unusual opportunity to participate and contribute to a dynamic and rapidly evolving field within the profession. Most foresters' work is heavily reliant on methods developed and research conducted decades ago, but the challenges posed by climate change are a chance to test new strategies, approaches, and tools. These new actions will inform management at the present time as well as benefit future forests and the human communities that are dependent upon them.

The listening sessions were characterized by a high level of engagement, interaction, and mutual respect, while individuals' commitment was evident in the many thoughtful responses in the online questionnaire. Both are evidence of the active discussions that are taking place on the broad topic of forest adaptation. These informal networks provide opportunities for forestry professionals to exchange information and learn

from each other. Managers reported that opportunities to gather and discuss the complexities surrounding climate change help to make the issue more accessible and less overwhelming.



Using a variety of terms, forest managers identified communities of practice as providing a valuable way to improve their knowledge and inform their actions. These communities can take on many forms, but a core function is to provide a venue for collective learning in a shared domain. Individuals can gather through meetings, online exchanges, field tours, or other avenues tailored to the needs and interests of participants. Existing organizations such as professional societies, university extension programs, and landowner groups can often help support communities of practice.

For individuals and groups, communities of practice provide a mechanism for learning by revisiting past management decisions and projects. Professionals and landowners can visit the sites of past stewardship activities to view what actually happened and how it compares to the results that were hoped for. This knowledge is passed on and amplified by sharing outcomes and lessons learned. Monitoring the results of adaptation actions can also inform future management. Managers can determine the level of monitoring that is practical and appropriate for their needs, but activities from simply taking photographs to recording more detailed measurements are highly valuable for advancing knowledge on forest adaptation practices. The knowledge shared from tracking these actions and outcomes helps inform the community's collective knowledge of forest climate adaptation strategies.



CONCLUSION

The topic of climate change continues to grow and expand in a variety of ways. The original intention of this work was to characterize the current “temperature” of New England’s forestry community on climate adaptation in order help shape organizational programming and activities for NIACS, the Forest Stewards Guild, and other boundary-spanning organizations. The Northeast has long been a leader in considering climate change in forest management, with critical science information on climate impacts and forest responses going back well over a decade (5-10, 40-43). With this history and with diverse resources at hand, we found that many forest and natural resource professionals are actively confronting this issue and wanting to engage in discussions of how to respond to climate change.



On the surface, many of the needs and challenges expressed by managers reflect similar themes that NIACS has been hearing over a decade of adaptation work, which were used to develop the Climate Change Response Framework (4, 44, 45). Conversations regarding climate change have advanced substantially, however, and we see two major differences in how discussion of this topic have changed during this time:

- Natural resource managers are more actively participating in conversations about climate change, which is demonstrated by the large number of people who engaged in this effort and the eagerness with which they shared their thoughts.
- The information and research needs suggested by managers are growing in sophistication and nuance. For example, we see that managers are increasingly aware of generalized projections of climate change and forest impacts and asking more complex questions about secondary stressors (such as invasive species, insects, diseases) and complex ecosystem interactions.



It is the role of boundary-spanning and science support organizations like NIACS and the Forest Stewards Guild to address new developments in scientific information and forestry practice in order to advance the adoption of new approaches. To this end, we see several opportunities to advance climate change adaptation and bring together new science and new management approaches to ensure that forest benefits are sustained over the long term.



- The Climate Change Response Framework was developed about ten years ago to address the greatest barriers to climate change adaptation by fostering collaborative partnerships, assessing climate vulnerabilities, developing adaptation resources, and providing demonstrations of on-the-ground adaptation. The perspectives shared by managers during this needs assessment point to a variety of ways that these efforts were successful in advancing climate change discussions in New England during the past five years of CCRF work in the region. Managers also point to new and emerging needs for integrating climate change considerations into their management—many of which can be addressed by continued and enhanced CCRF activities. Future CCRF efforts will focus on making current products more widely available and on generating new products to address new and increasingly complex questions.
- Many of the participants in the needs assessment have participated in climate adaptation trainings led by NIACS or in workshops or field tours led by the Forest Stewards Guild or NIACS. Their continued engagement in the topic suggests that these types of activities are an effective way to increase the overall “literacy” of professionals and help managers to understand the latest climate change science, as well as its current limitations. We will provide more educational opportunities and more advanced offerings in order to increase the number of individuals who are engaging in climate change as a management concern, address the specific questions raised by practitioners in this needs assessment, and raise the collective level of understanding among the broader community.



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- Communities of practice vary widely, but center around a core topic or subject of interest, an engaged community, and a collection of resources and outputs as a means to solve complex problems (46, 47). In convening scientists and managers to discuss the current state of climate change adaptation, we found that a community of practice is already coalescing around this issue. The Forest Stewards Guild and NIACS will work together to continue convening this emerging community and create more formalized work groups for advancing identified issues. Efforts are underway to formalize a community of practice within southern New England, with the expectation that additional regional communities will be formed in the next 1-2 years.
 - The Forest Stewards Guild and NIACS will facilitate connections and engage in projects that meet the needs identified by New England's community of practice. For example, the Guild is working with partners in Rhode Island, Connecticut, and Massachusetts to increase resiliency in southern New England's oak forests while NIACS is leading a work group focused on forest adaptation. In Maine, the Guild is working with partners to share valuable climate-related forest research at the University of Maine and engage woodland owners in eastern Maine in forest management practices that benefit the region's woods, waters, and wildlife.

The land managers who participated in this work identified many challenges to forest management, perhaps the greatest of which is the inherent uncertainty of what the future holds. At the same time, many foresters pointed to actions that are being or can be taken to enhance the ability of forests to adapt. Notably, while many managers pointed to the need for a community of practice for addressing climate change, what emerged most clearly was evidence that such a community (or multiple communities across different and overlapping geographies) already exists and is poised to move forward.

This report characterizes the current state of this community and points to the next steps to advance climate adaptation. It identifies new scientific information that will advance our understanding of the issue and increasingly help managers prioritize and address the greatest risks. Further, as more managers engage in intentional adaptation practices and share their stories, the community will have greater knowledge of effective practices in diverse contexts. By working together, we can overcome barriers so that forests and human communities are able to proactively anticipate and respond to change.



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