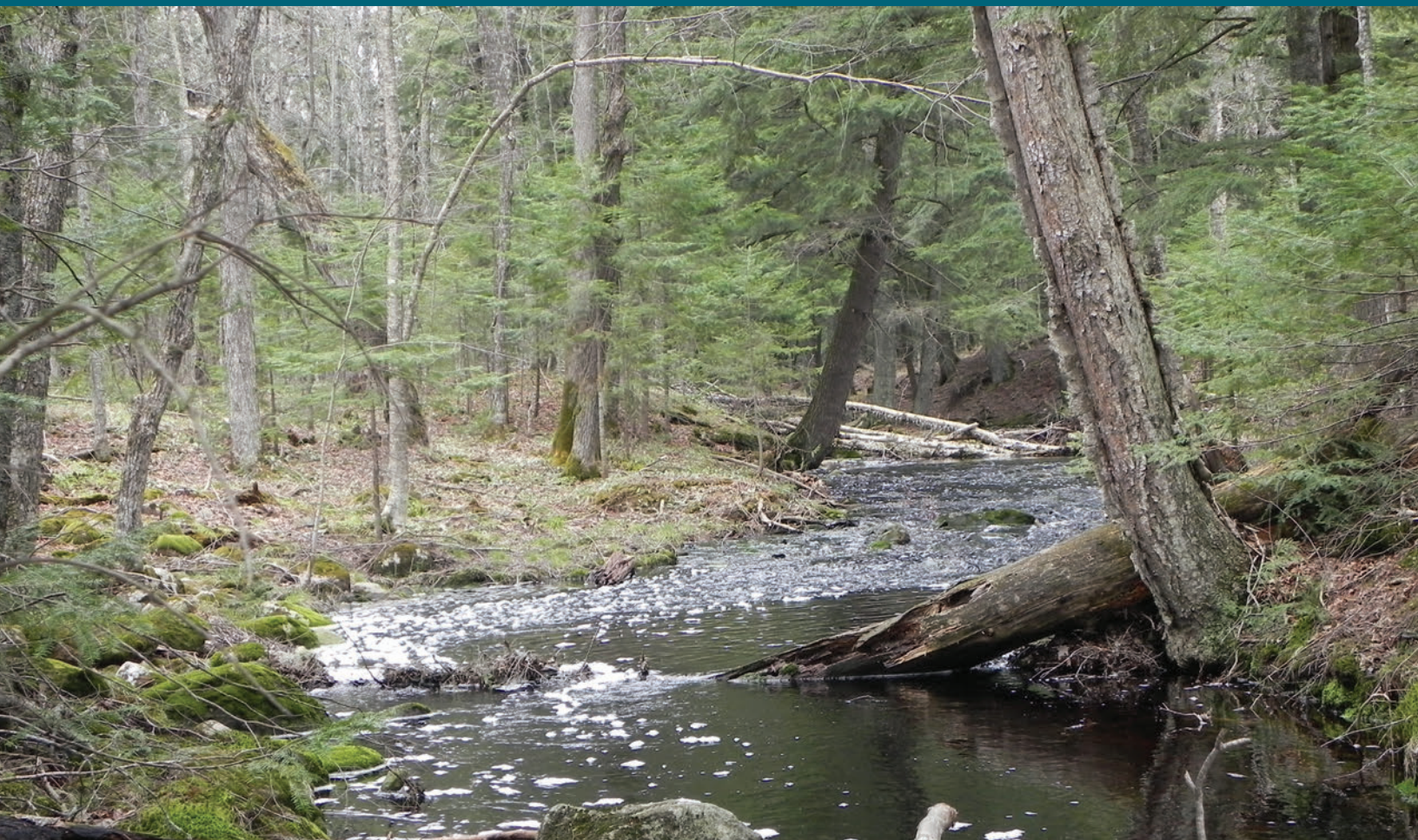


# Climate Change Science Applications and Needs in Forest Ecosystem Management

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Northern  
Research Station

## ABSTRACT

Climate change is leading to direct and indirect impacts on forest tree species and ecosystems in northern Wisconsin. Land managers will need to prepare for and respond to these impacts, so we designed a workshop to identify forest management approaches that can enhance the ability of ecosystems in northern Wisconsin to cope with climate change and address how National Forests and other lands could be used to test these approaches. The workshop had three major themes: (1) adaptation of forest management to current and expected climate change, (2) forest management to support greenhouse gas mitigation, and (3) monitoring of climate change impacts and the effectiveness of mitigation and adaptation strategies. A group of nearly 60 experts in the fields of forest science, policy, and forest resource management identified place-based management approaches and new research directions that addressed these major themes. One concept that emerged was the need to adapt not only ecological systems but social systems as well, and research to adapt social systems was identified as a key knowledge gap. Participants were cautious about the potential for northern Wisconsin lands to mitigate greenhouse gas emissions and enhance carbon sequestration through forest management. The experts identified the need for more research to quantify that potential, especially for non-forested lands and greenhouse gases other than carbon dioxide. Participants also agreed that mitigation strategies will not be effective in the long term unless they are carried out in conjunction with adaptation strategies. According to participants, current monitoring efforts in northern Wisconsin are insufficient to detect climate change impacts at spatial scales relevant to land management and are not as well-integrated with each other as they could be. However, participants identified several regional and national programs that could serve as models for integration. Outcomes from this workshop emphasized the importance of a place-based response to climate change. Forest managers in northern Wisconsin will need to establish and articulate clear goals for adaptation, mitigation, and monitoring, as well as ensure these goals are integrated with one another, in order to be effective at responding to climate change.

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### Cover Photo

The Chequamegon-Nicolet National Forest in Wisconsin. Photo by Maria Janowiak, U.S. Forest Service.

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# **Climate Change Science Applications and Needs in Forest Ecosystem Management**

**A workshop organized as part of the  
Climate Change Response Framework Project  
in northern Wisconsin**

**April 27-28, 2010, Madison, WI**

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# Executive Summary

The two objectives of our workshop were (1) to identify management approaches that can enhance the ability of ecosystems in northern Wisconsin to cope with climate change and (2) to address how National Forests and other lands may be used to test new approaches. Workshop sessions were centered on adapting to current and projected climate change impacts (adaptation), reducing greenhouse gas emissions and enhancing carbon storage (mitigation), and monitoring climate change impacts and the effectiveness of adaptation and mitigation strategies. We asked participants to identify existing science that could influence current management decisions, as well as information gaps that could be addressed scientifically in northern Wisconsin.

Participants suggested potential strategies that could be considered for forest management in northern Wisconsin. The suggested strategies are not a comprehensive list of every action that could be taken, nor are they recommendations. Rather, they serve as a starting point for conversation when developing plans for climate change response in northern Wisconsin.

## Adaptation

Participants identified the following adaptation strategies to be relevant to northern Wisconsin forests and worthy of further consideration:

**Resistance strategies** (resisting change to preserve current conditions)

- A-1. Identify and maintain potential refugia for threatened species and ecosystems.
- A-2. Reduce existing stressors.

**Resilience strategies** (returning ecosystems to prior conditions after disturbance)

- A-3. Maintain and increase species and genetic diversity.
- A-4. Maintain or improve hydrologic conditions in lowland ecosystems.
- A-5. Manage to increase and maintain edaphic conditions and structure.
- A-6. Restore fire to ecosystems that previously depended on it.

**Response strategies** (assisting the transition of ecosystems to new environmental states)

- A-7. Increase the pool of genetic diversity when planting.
- A-8. Preserve and improve connectivity across the landscape.
- A-9. Assess the viability of current forest types.
- A-10. Position infrastructure to support response to climate change.
- A-11. Plan for disturbance.
- A-12. Identify newly suitable habitats.

## Organizational capacity

- A-13. Develop adaptive policies.
- A-14. Integrate upscaling and downscaling of information into adaptation strategies.
- A-15. Increase information transfer with people in the surrounding landscape and manage social expectations.
- A-16. Create a prioritization process for implementing adaptation strategies.
- A-17. Develop and utilize templates or tools to systematically assess climate change impacts and management activities.

Additional research needs to help inform these adaptation strategies were:

- Understand what factors contribute to refugia (Strategy A-1).
- Increase research in plant genetics (Strategies A-3, A-7).
- Develop better models to predict changing hydrologic regimes (Strategy A-4).
- Assess the quality or viability of ecosystem services from existing and novel forest types (Strategies A-9, A-12).
- Find analogs (or identify the lack thereof) that represent a range of future climates in order to predict future species ranges (Strategies A-9, A-12).
- Conduct experiments with species to test model predictions on the ground (Strategies A-9, A-12).
- Determine the feedbacks of management and disturbance on climate (Strategy A-11).
- Based on ecological assessments, undertake a social/economic assessment with the affected public to explore the idea of managing with uncertainty and short-term and long-term consequences of climate change (Strategies A-13, A-14, A-15, A-16).

## Mitigation

Participants identified the following mitigation strategies and considerations to be relevant to northern Wisconsin forests:

### Enhanced sequestration

- M-1. Evaluate practices that have mitigation potential and align with strategies for adaptation and general ecosystem health.
- M-2. Include both wetlands and forests in carbon management strategies.
- M-3. Consider extending northern hardwood rotation periods for carbon storage, but be mindful of carbon sequestration rates among various age classes.
- M-4. Consider increasing stocking, but be mindful of increased susceptibility to fire.
- M-5. Account for age structure and composition at multiple temporal and spatial scales when developing a carbon storage and sequestration strategy.
- M-6. Weigh other values when devising management strategies to increase carbon sequestration.
- M-7. Consider the role of both public and private lands in carbon sequestration strategies.
- M-8. Identify high-priority areas for sequestration activities.

### Bioenergy and substitution

- M-9. Be aware of the limitations of bioenergy.
- M-10. Consider marginal agricultural lands and alternative species mixes for bioenergy production.
- M-11. Monitor where the demands are likely to increase with respect to bioenergy.



Additional research needs to help inform these mitigation strategies were:

- Increase understanding of management effects on belowground processes and soil carbon sequestration effects (Strategy M-1).
- Address the role of other greenhouse gases such as methane and nitrous oxide and non-forest landscapes such as wetlands (Strategy M-2).
- Mine data on carbon and management activities from the past to direct future management of carbon (Strategies M-3, M-4, M-5).
- Conduct research on carbon mitigation across ownership boundaries (Strategy M-7).
- Provide information to public managers and private landowners interested in carbon markets on how much sequestration they can obtain under different management scenarios (Strategy M-7).
- Assess the ecological consequences of carbon mitigation, with a particular emphasis on tradeoffs related to biomass energy and other resources (Strategies M-9, M-10).
- Conduct an economic analysis of ways to offer incentives for carbon mitigation activities across the landscape (Strategies M-6, M-7, M-11).
- Develop a research consortium to evaluate different strategies for carbon management under a changing climate (All strategies).

## Monitoring

Participants identified the following monitoring strategies to be relevant to northern Wisconsin forests:

### Monitoring impacts

- Develop a network of existing monitoring networks.
- Monitor species and ecosystem processes that are sensitive to climate change and could serve as early indicators, keeping cost in mind.
- Monitor climate directly.
- Consider a research-management partnership.
- The Chequamegon-Nicolet National Forest (CNNF) could develop a research-monitoring team to help the Forest better integrate monitoring data into management and could appoint a research liaison.
- Increase the spatial and temporal scale of monitoring in key areas on the landscape.
- Ensure that organizations complement one another's monitoring efforts.
- Outline monitoring goals and protocols well before monitoring begins.

### Monitoring the effectiveness of adaptation and mitigation strategies

- Identify cost-effective indicators or suites of indicators to streamline effectiveness monitoring.
- Consider conducting a purposeful outside review of Forest Service monitoring protocols.

- Capitalize on collaboration and partnerships with other organizations.
- Set mitigation goals and monitor carbon storage.
- Use monitoring data to influence institutional behavior.
- Close the loop on the adaptive management circle: lessons from effectiveness monitoring should feed back into management actions.

## Major Workshop Themes

1. In order to be effective at responding to climate change, forest managers in northern Wisconsin need to establish clear goals for adaptation, mitigation, and monitoring and make sure these goals are articulated and integrated.
2. Land managers and scientists alike need to remember that all management decisions will ultimately be made in a social and economic context.
3. Change in the way forests are managed in response to climate change requires a large investment of time and resources from a diverse group of experts and stakeholders.
4. Science and management need to be much better integrated to effectively respond to climate change in forest management.

# Introduction

There is overwhelming evidence that global mean temperatures are increasing and will continue to do so, largely as a result of rising greenhouse gases concentrations in the Earth's atmosphere (Intergovernmental Panel on Climate Change [IPCC] 2007, National Research Council [NRC] 2010). This increase in temperature, in turn, is leading to changes in precipitation and disturbance regimes at local and regional scales in the United States (U.S. Global Change Research Program [USGCRP] 2009). Changes in temperature, precipitation, and disturbance regimes are projected to have direct and indirect effects on forest tree species and ecosystem processes (for example, Dale et al. 2001, Iverson et al. 2008, Scheller and Mladenoff 2008, Woodall et al. 2009, Xu et al. 2009), creating a pressing need for changes in ecosystem management to adapt to these changes. Forest management also has the potential to mitigate greenhouse gas emissions to some extent, as forests store carbon in above- and belowground biomass and soil (Rhemtulla et al. 2009, Ryan et al. 2010).

The U.S. Forest Service's mission is to "sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations" (U.S. Forest Service 2008). Maintaining healthy, diverse, and productive forest ecosystems for future generations is important for the multiple benefits they provide, including supplying ecosystem services such as clean drinking water, supporting

an economically viable timber industry, helping to support alternative energy from biofuels, providing recreation opportunities, and providing habitat for fish and wildlife, including many threatened and endangered species (Barnes et al. 2009, Loomis and White 1996, National Visitor Use Monitoring Program 2010, Skog and Rosen 1997). Managing National Forests for multiple uses and benefits could become increasingly difficult under a rapidly changing climate unless local action is taken in the near future to adapt ecosystems and management systems to climate change and mitigate the amount of greenhouse gases that are released to the atmosphere (Joyce et al. 2008). However, most guidance to date on responding to climate change in forest ecosystem management has been quite broad, making it difficult for land managers to act locally.

Several broad strategies for ecosystem management in response to climate change have been suggested (Heller and Zavaleta 2009, Millar et al. 2007, Spittlehouse and Stewart 2003). A few place-based approaches to forest ecosystem management have also been developed with a primarily academic focus (Fissore et al. 2009, Galatowitsch et al. 2009, Nitschke and Innes 2008). Recently, some approaches have involved direct input from land managers and policy-makers (Aubry et al. 2011, Littell et al. 2011, Manomet Center for Conservation Sciences & Massachusetts Division of Fisheries and Wildlife [Manomet and DFW] 2010). However, these place-based approaches remain few, and so far

have covered only a limited number of geographic areas, specifically western Washington (Aubry et al. 2011, Littell et al. 2011) and Massachusetts (Manomet and DFW 2010).

Previous attempts at developing climate change strategies have tended to emphasize either **mitigation approaches**<sup>1</sup>, which focus on increasing carbon storage or reducing greenhouse gas emissions, or **adaptation approaches**, which focus on increasing the ability of an ecosystem to resist or respond to climate change. However, mitigation and adaptation approaches are best considered together, since the degree of mitigation affects the amount of climate change for which forest managers will need to adapt, and adaptation is necessary to ensure that forests will continue to sequester carbon in the future (Joyce et al. 2008). It is also critical to consider these approaches across a broad range of spatial and temporal scales when evaluating them for effectiveness.

Climate change response strategies seldom include an explicit focus on **monitoring**, even though it is essential for informed decisionmaking (Marsh et al. 2009). Monitoring, both on-the-ground and remote sensing, allows us to detect changes in climate and its impacts, and evaluate management decisions' effectiveness in adapting to climate change (NRC 2010). In addition, extensive monitoring is necessary to estimate the amount of carbon stored in forest systems and assess potential changes in carbon stocks over time (Birdsey et al. 2009).

Climate change introduces a new level of uncertainty to land management. Global climate models vary widely in their projections, especially

with respect to seasonal precipitation patterns (Bader et al. 2008). In addition, future greenhouse gas emissions are a major controlling factor of climate change, but will depend largely on future political, economic, technological, and social conditions that are difficult to predict (IPCC 2007). However, many management actions can be taken today. In fact, many decision frameworks already exist that are designed to incorporate uncertainty of future outcomes. The uncertainty of climate change fits well into the ideas of **adaptive management** and **risk management**. These approaches, taken either together or separately, can provide a framework for decision-making and action even as we cope with the uncertainties of climate change and forest response (NRC 2010).

Recognizing the management challenges associated with uncertain future conditions, the U.S. Forest Service Eastern Region identified the Chequamegon-Nicolet National Forest (CNNF) and the surrounding landscape of northern Wisconsin (defined by Ecological Province 212, Mixed Laurentian Forest; Fig. 1) as a "Climate Change Model Forest for Landscape Management."<sup>2</sup> Northern Wisconsin possesses a convergence of three major biomes: eastern deciduous forest in the southeast, boreal forest in the north, and tallgrass prairie in the southwest. The area also has a large concentration of wetlands with organic soils that store large amounts of carbon. The southern border of the area is marked by a climatic tension zone which has markedly distinct temperature and precipitation regimes on the northeast and southeast sides, resulting in a large differentiation in plant communities on

<sup>1</sup>Definitions of words in bold print can be found in the Glossary.

<sup>2</sup>For a more detailed description of the CNNF, its ownership patterns, and its ecology, see the *Ecosystem Vulnerability Assessment and Synthesis* (Swanston et al. 2011, Appendix 1).

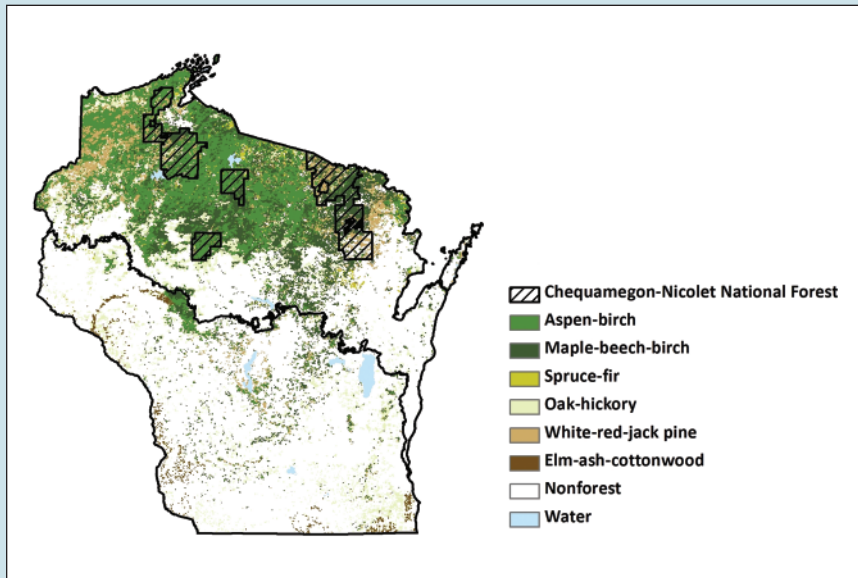


Figure 1.—This map of Wisconsin shows the borders of the Chequamegon-Nicolet National Forest, along with the dominant forest types in the surrounding area as described by the Forest Service’s Forest Inventory and Analysis program. The workshop focused on the area north of the diagonal black line intersecting the state. (Illustration used with permission of Patricia Butler, Michigan Technological University and Northern Institute of Applied Climate Science.)

either side (Curtis 1959). Northern Wisconsin is also bordered by Lake Superior to the northwest and Lake Michigan to the east, which have strong effects on local precipitation regimes and mitigate temperature extremes to some extent. Northern Wisconsin is a heavily forested area with multiple ownerships: the majority of the forested land is privately owned (59 percent; Swanston et al. 2011), with the remainder comprising State (6 percent), county/town (17 percent), tribal (4 percent), and Forest Service lands (13 percent). The CNNF is dispersed across northern Wisconsin and is surrounded by local government-owned and private lands. The economy of northern Wisconsin relies heavily on forest ecosystems for timber and recreational purposes.

We designed a workshop to **identify management approaches that can enhance the ability of ecosystems in northern Wisconsin to cope with climate change and address how National Forests and other lands may be used to test**

**new approaches.** The workshop also initiated a Climate Change Science Roundtable for northern Wisconsin, with a goal to increase cooperation between the research and forest management communities. This workshop was part of a larger effort to develop a “Climate Change Response Framework” (CCRF) for northern Wisconsin with a goal of serving as a model for climate change adaptation and mitigation for National Forests and other public and private forest lands both regionally and nationally. We took an integrated approach to responding to climate change in northern Wisconsin, focusing on the intersection of adaptation, mitigation, and monitoring from scientific, management, and policy perspectives (Fig. 2). In addition to the workshop described here, the initial development of the Framework consisted of an ecosystem vulnerability assessment (Swanston et al. 2011), a greenhouse gas mitigation assessment, and a Shared Landscapes Initiative to engage stakeholders and develop partnerships in the

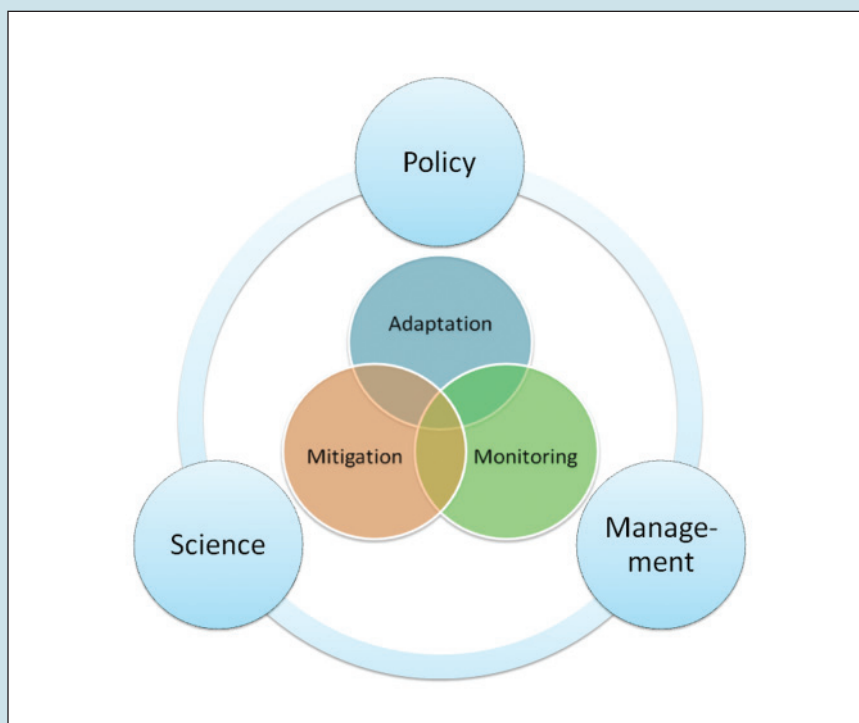


Figure 2.—Workshop participants discussed adaptation, mitigation, and monitoring approaches for responding to climate change from science, policy, and management perspectives. (Illustration by Leslie Brandt, U.S. Forest Service.)

surrounding landscape (Appendix 1). The CCRF will provide information and resources to better adapt ecosystems to changing climate, mitigate carbon emissions, respond to climate change impacts across ownership boundaries, and rapidly incorporate science and monitoring information into management activities on the CNNF and other forests in northern Wisconsin. This workshop and the other three components helped inform the CCRF, and provided input into *Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers* (Janowiak et al. in press), a document that describes adaptation strategies and approaches and assists land managers with developing tactics (Appendix 1).

## Workshop Structure and Approach

Our workshop sessions were centered on climate change adaptation, mitigation, and monitoring with a specific focus on forest types in northern Wisconsin and the CNNF. We asked participants to identify existing science that could influence current management decisions, as well as information gaps that could be addressed scientifically in northern Wisconsin and within the CNNF in particular. The nearly 60 participants were regional and national experts in forest science, policy, and forest resource management, and represented state, federal, non-governmental, and educational institutions (Appendix 2). Since participants varied in their expertise on each of

the three focus areas (adaptation, mitigation, and monitoring) and in their expertise on northern Wisconsin forests in general, they were provided with climate change mitigation and vulnerability assessments for northern Wisconsin prior to the workshop and were given breakout session questions ahead of time. A workshop launching the Shared Landscapes Initiative (SLI) was held 2 months prior to the science workshop (Appendix 1). That workshop was primarily attended by federal, state, local, and private landowners and managers in northern Wisconsin, who helped to provide a perspective on the management concerns related to climate change in the surrounding landscape of Province 212 of Wisconsin. A summary of the SLI workshop was also provided to the participants of the science workshop.

The workshop began with opening remarks from Forest Service leaders that provided context on science, policy, and management integration, and plenary talks on climate change in northern Wisconsin forests.<sup>3</sup> Conceptual framework talks prior to each breakout session on adaptation, mitigation, and monitoring set the stage and provided a common language for breakout sessions.

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<sup>3</sup>Biographies of speakers are provided in Appendix 3.

Breakout sessions followed each conceptual framework talk and addressed:

1. How can our current knowledge be applied to management activities in northern Wisconsin?
2. What additional research or data are needed to move forward?

Participants were divided into three randomly assigned groups for each theme (approximately 20 people per group). A facilitator for each group led a brainstorming session aimed at addressing questions specific to the theme. Overarching ideas from each group were shared among groups and are synthesized below. Ideas generated in the breakout sessions outlined potential approaches that *could* be adopted by managers, policy-makers, or scientists on the CNNF or the surrounding landscape of northern Wisconsin. These approaches will be assessed for their potential for incorporation into the CCRF based on their benefits, feasibility, and other considerations.

## Opening Remarks

Chris Swanston, Director of the Northern Institute of Applied Climate Science and a research ecologist for the Forest Service, Northern Research Station, outlined the goals and objectives of the workshop and explained how the workshop fits into the larger CCRF Project. Swanston laid out the expectations for the workshop participants: that they be fully engaged and contribute to frank and forthright discussion. Swanston also invited all participants to become part of the Climate Change Science Roundtable for northern Wisconsin, which has a goal to increase cooperation between the research and forest management communities and to help facilitate research activities and technology transfer related to climate change impacts on northern Wisconsin forests.

David Cleaves, Climate Change Advisor to the Chief of the Forest Service, set the national context for the Forest Service's response to climate change. He emphasized that increasing resilience to climate change is one of four "pillars" of the Forest Service's vision for America's forests. He emphasized five things the Forest Service must do in responding to climate change:

- Assess risks (vulnerabilities) under future scenarios.
- Invest in strategies, not just practices.
- Prioritize investments according to vulnerability and likelihood of success.
- Build trust and teamwork among agencies, citizens, and organizations.
- Build skill, capacity, and flexibility across institutions.

Cleaves said the focus on climate adaptation is a priority because: (1) it is required for sustained carbon sequestration and greenhouse gas mitigation, (2) the warning signs are clear, and (3) it is the mission of the Forest Service to "sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations" (U.S. Forest Service 2008). He noted that adaptation does not mean starting from scratch or shifting priorities. The Forest Service could build on what is already known about ecosystems and incorporate climate change into existing plans and programs. Cleaves encouraged participants to take action immediately because one "can't steer a bicycle unless it's moving." According to Cleaves, the Forest Service could be a leader in climate adaptation because of its complementary mission areas, body of proven knowledge and skill, mission and authorities, geographic diversity, world-class research, network of partners, and energetic and professional workforce.

Kent Connaughton, Regional Forester for the Eastern Region of the National Forest System, talked about the goal of using the CNNF and the surrounding forests of northern Wisconsin as a "model landscape" for climate response in the East. Connaughton emphasized the need to conserve forests in the United States and view eastern National Forests and the public and private forests that surround them as instruments of public policy. The challenge, Connaughton stated, is how to assess the outcome over a long period of time. Faced with a lack of information, managers,



scientists, and policy-makers need to be nimble in dealing with uncertainty. Confronting a lack of governance on climate change, federal personnel need to align their research and managerial priorities with state priorities. However, Connaughton urged the Forest Service not to let the past dictate the future. The boundaries between science and land management cannot be distinguished, and these two areas need to work together to address climate change.

Thomas Schmidt, Assistant Director of Research for the Forest Service's Northern Research Station, emphasized the support that the Northern Research Station had for utilizing National Forests as "living laboratories." Such living laboratories as the CNNF are necessary for incorporating science into decisionmaking. Schmidt stated that the research community must be integrated into management and cited the northern Wisconsin CCRF project as an outstanding example of that process.

# Plenary Talks

## Climate Projections for Northern Wisconsin

Michael Notaro described how climate is projected to change in Wisconsin over the next century using **statistical downscaling** and **debiasing** of 14 global climate models under three emission scenarios. His results indicated that mean daily temperature in Wisconsin was projected to increase by an average of 6.1 °F (3.4 °C) by 2055 compared to the 30-year average from 1950-1980. Warming was projected to increase more at night and inland from lakes Superior and Michigan. The models projected a general increase in annual precipitation, especially during the winter months, but models tended to be inconsistent on projections of precipitation during the summer months. Therefore, Notaro cautioned that current projections of summer precipitation should not be used in decisionmaking for northern Wisconsin, but he also said that moisture availability will likely decrease during the summer because higher temperatures will increase **evapotranspiration**.

Notaro showed that shifts in temperature and precipitation will lead to continued lengthening of the growing season, a northward shift in plant hardiness zones, and a northward movement of Wisconsin's climatic **tension zone** (Fig. 3). By the end of the century, heavy precipitation events were projected to increase in frequency and snowfall and snow depth were projected to decrease.

## Regional Impacts of Climate Change on Forests

Louis Iverson presented the results of a modeling effort to examine climate change impacts on potential habitat ranges of tree and bird species. Iverson and his team developed statistical models based on current climate, current bird and tree species distributions, and other environmental factors such as soil characteristics and elevation. These models are then adjusted for modeled future climate, and potential future habitats are identified. The results of this modeling effort, presented in an online *Climate Change Atlas*<sup>4</sup> (Iverson et al. 2008), showed potential “winners and losers” under climate change. For northern Wisconsin, tree species at the southern extent of their range with very narrow habitat ranges, such as black spruce (*Picea mariana*) and balsam fir (*Abies balsamea*), were projected to have the greatest loss of suitable habitat. Species that were adapted to disturbance or had a wide range of tolerances, such as red maple (*Acer rubrum*), or were at the northern extent of their range, such as several oak (*Quercus*) species, fared better.

Iverson cautioned that the models of suitable habitat did not take into account lag times in the ability of trees to migrate or the effects of

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<sup>4</sup>Links to more information on programs and websites (in italics throughout the document) can be found in Appendix 4.

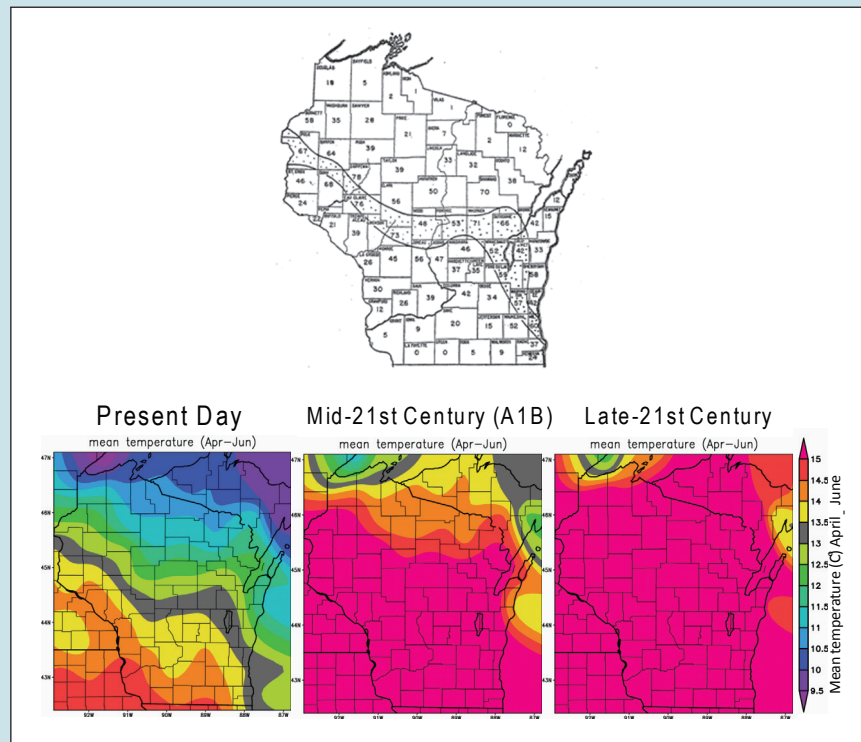


Figure 3.—Michael Notaro showed that Wisconsin's tension zone (depicted in gray), determined largely by spring temperatures, is projected to move northward, and may move out of the state entirely by the end of the century, even under a mid-range greenhouse gas emission scenario (A1B). (Illustration used with permission of the University of Wisconsin Press and David Lorenz, University of Wisconsin.)

other “modifying factors” that could make some species fare better or worse than models predict (Fig. 4). For example, while oaks are likely to have more suitable habitat in northern Wisconsin in the next 100 years, migration of the species into the new habitat may be slow, or prevented altogether across the fragmented landscape. In another example, several ash (*Fraxinus*) species would normally be projected to persist, albeit at lower levels, in northern Wisconsin under a changing climate, but the probable future impacts of the emerald ash borer (*Agrilus planipennis*) are likely to overwhelm any effects of climate change. Iverson addressed limited dispersal ability using a model called SHIFT, and addressed modifying factors using a qualitative ranking system through a literature review. The results are a major component of the *Ecosystem Vulnerability Assessment and Synthesis* (Swanston et al. 2011).

## Climate Change, Management, and Disturbance in Northern Wisconsin Forests

David Mladenoff showed that in order to truly understand climate change impacts, scientists and managers must also understand how the interactions among management, disturbance, and climate have influenced ecosystems of northern Wisconsin in the past, and how they will continue to do so in the future. Prior to European settlement, the landscape of northern Wisconsin was heavily influenced by fire and wind disturbances. These disturbance regimes resulted in multi-cohort stands in the forests of northern Wisconsin, dominated by white pine (*Pinus strobus*), oak, hemlock (*Tsuga canadensis*), and mixed hardwoods. Management and land use change after European settlement led to a

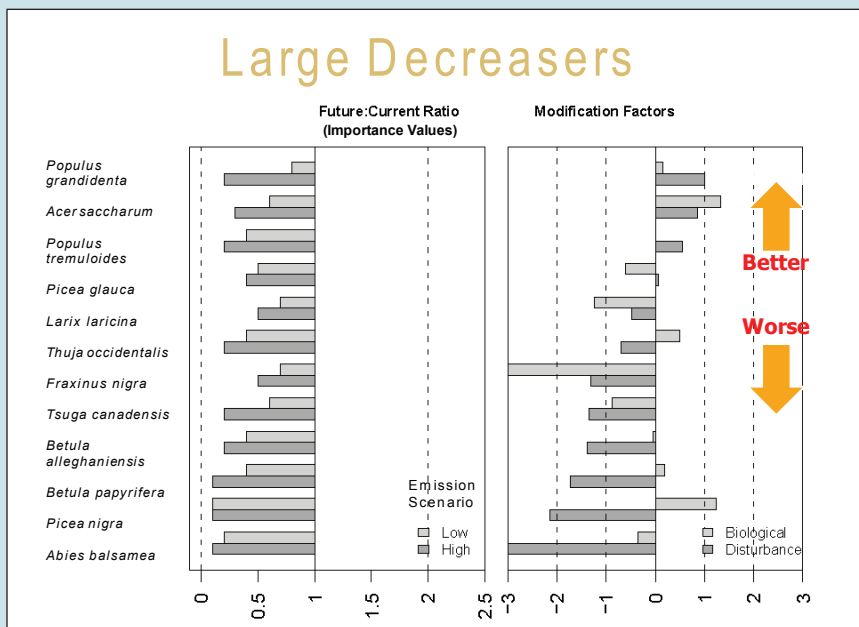


Figure 4.—Louis Iverson showed that some species projected to decrease in importance value under climate change (large decrease) may fare better than predicted over the next century because of “modifying factors.” Modifying factors can be biological characteristics, such as dispersal and regeneration ability, or disturbance, such as fire or insect damage. Black ash, for example, has a negative modifying factor because it has a highly specialized habitat and is susceptible to the emerald ash borer. Aspen species have positive modifying factors because they reproduce clonally and respond positively to disturbance. (Illustration by Louis Iverson, U.S. Forest Service.)

decrease in the amount of forested land, a shift to dominance of even-aged stands, and increases in aspen (*Populus* spp.) and other hardwood species (Scheller and Mladenoff 2008).

Mladenoff presented the results of his simulation model, LANDIS-II, which examined the interactions among climate change, disturbance, and management on tree species distribution. His models showed that landscape fragmentation and

management will affect the ability of trees to move to suitable habitats in a changing climate (Fig. 5). These results showed that southern species, such as oak and hickory (*Carya* spp.), would be slow to arrive and take advantage of a warmer climate with potentially drier soil and a greater potential for fire. The results of Mladenoff’s work also served as a key component of the *Ecosystem Vulnerability Assessment and Synthesis* (Swanston et al. 2011).

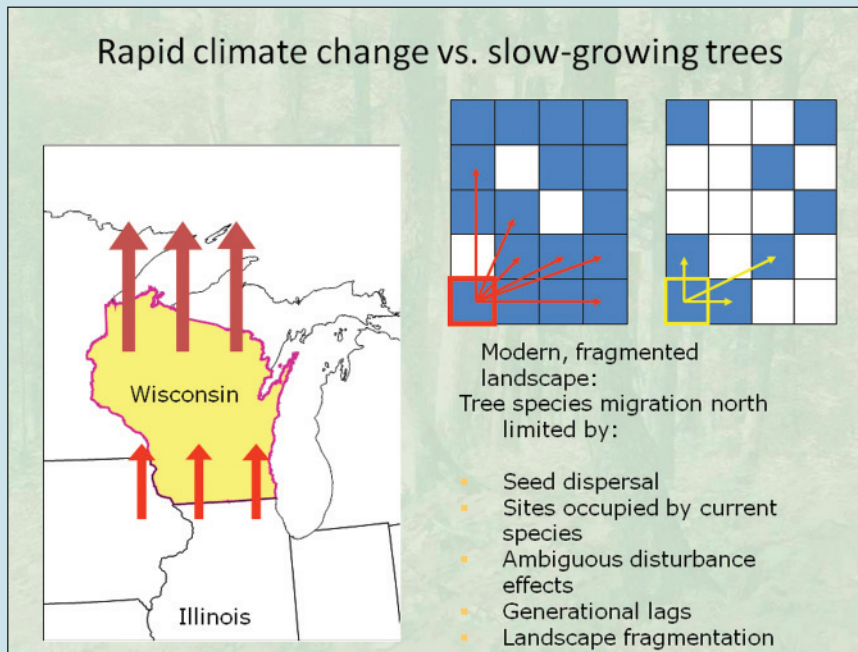


Figure 5.—David Mladenoff showed that while climate change is occurring rapidly, tree growth and migration will not be able to keep up, due to natural inability to disperse and grow rapidly, or because landscape fragmentation by human development creates barriers. The boxes represent landscapes with different levels of fragmentation. Blue squares represent areas where a tree could potentially migrate (forested areas), while white squares represent uninhabitable areas. Arrows indicate potential tree dispersal. (Illustration used with permission of David Mladenoff, University of Wisconsin.)

# Breakout Session 1: Adaptation

## Conceptual Framework Talk: Climate Change, Resource Management, and Adaptation

Linda Joyce presented a conceptual framework for adaptation that could be applied to forest ecosystem management in northern Wisconsin. First, she outlined four general strategies for responding to climate change: resistance, resilience, response, and realignment (Millar et al. 2007):

- **Resistance** is an adaptation option intended to improve the defenses of a forest against anticipated changes or directly defend the forest against disturbance in order to maintain relatively unchanged conditions.
- **Resilience** is an adaptation option intended to accommodate some degree of change, but allow for a return to prior conditions after a disturbance, either naturally or through management.
- **Response** is an adaptation option to accommodate change and enable ecosystems to adaptively respond to changing and new conditions.
- **Realignment** is the process of tuning ecosystems or habitats to present and anticipated future conditions in such a way that they can respond adaptively to ongoing change.

Joyce said that all of these strategies can be part of a toolkit for adapting forests to climate change and can be mixed and matched or adjusted between the short term and long term. She emphasized that all approaches require a prioritization process; she used **triage** as an example. Evaluating an organization's adaptive capacity and timing in its response was also cited as an important component of any adaptation efforts (Fig. 6). Joyce stated that land managers will have to decide when it would be best to take no adaptation actions, when to take adaptation actions associated with current goals, and when to plan or act for change.

## Adaptation Breakout Session Goals

The overall goal of the adaptation breakout session was to identify approaches and activities to help forests in northern Wisconsin adapt to climate change.

Participants were asked the following specific questions:

1. How can our current knowledge be applied to adaptation strategies for northern Wisconsin forests?
2. What additional research activities would help us fill in our current gaps in understanding that impede progress in adaptation?

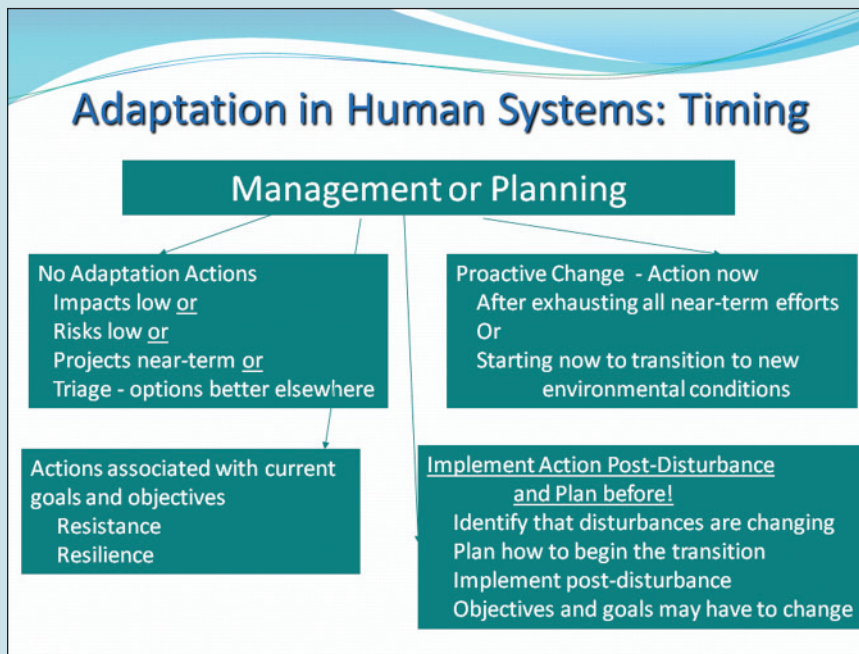


Figure 6.—Linda Joyce emphasized the need to make decisions on timing of adaptation actions. Actions can be associated with current goals and objectives, can be proactive, or can be a planned action in response to a disturbance. (Illustration by Linda Joyce, U.S. Forest Service.)

Participants identified approaches and activities falling under the general strategies of resistance, resilience, and response presented by Joyce that could be applied to northern Wisconsin forests given our current scientific understanding (specific realignment approaches were not identified). They also identified some changes that would need to be made to the adaptive capacity of organizations to better prepare for climate change. It is important to note that these strategies have not been vetted across disciplines or scrutinized for viability and sustainability; they could include some strategies that will ultimately be deemed unsuitable in many landscapes or for particular land uses. Additional research needs were identified to address gaps in understanding. Strategies are numbered in no particular order. For each research need, the corresponding strategy numbers that they help address are listed in parentheses.

## Application of Current Knowledge

### Resistance strategies

#### A-1. Identify and maintain potential refugia for threatened species and ecosystems.

- Managers could work with researchers to determine which landform, atmospheric, and associated species indicators determine **refugia** and incorporate these factors into a predictive model. Using these models, managers and scientists could identify the coolest and wettest sites that may act as potential refugia for lowland conifer and lowland hardwoods, two forest types that are projected to be vulnerable under a changing climate.

- Conifers provide a key habitat for threatened and endangered bird species, so enhancing conifer components in systems where they are projected to persist could be an option for providing refugia for bird species.
- Since deer herbivory poses a threat to many plant species now and into the future, Forest Service staff could work with the Wisconsin Department of Natural Resources to identify areas with low deer populations; these areas could act as refugia for species sensitive to herbivory.
- Hemlock and yellow birch (*Betula alleghaniensis*) are two species projected to decline under climate change. Using a triage process, managers could make these species a conservation priority and identify refugia for them.
- Building small dams or retention ponds in areas where high soil moisture needs to be maintained locally could be considered in order to preserve refugia. This option needs to be weighed against potential negative impacts on organism passage and sediment loading, but could be considered in cases where preservation of threatened and endangered species is a goal.

#### A-2. Reduce existing stressors.

- Managers could work to prevent the establishment of invasive plant species in newly disturbed areas, especially low-lying areas. For example, invasion of reed canarygrass (*Phalaris arundinacea*) can be a problem in lowland hardwood systems. Managers could consider experimental plantings, under-plantings, and manipulations in lowland systems to minimize colonization by reed canary grass.
- Fire suppression could be targeted in areas that are extremely susceptible to drying, such as coarse-textured glacial-fluvial areas.
- Minimizing disruption to forest canopy within the watershed of ephemeral ponds could help buffer them against hydrologic and temperature changes. Canopy cover can reduce evaporation and maintain temperatures that are cooler than the surrounding landscape.

### Resilience strategies

#### A-3. Maintain and increase species and genetic diversity.

- Managers could work to maintain and restore diversity of native tree species, focusing on regenerating rare, uncommon, or declining species such as hemlock.
- Restoration of a rich native ecosystem composition in the short term could help ensure that potential long-term winners (species, genotypes) are present.

#### A-4. Maintain or improve hydrologic conditions in lowland ecosystems.

- Managers could re-establish or maintain natural flow patterns in streams. Some areas may fare better if dams or other man-made structures are removed to allow water to reach some low-lying areas or to allow migration of aquatic species to more suitable habitats.



- Increased monitoring of hydrologic flows and conditions could help identify “trigger points” (thresholds) where climate change is affecting local hydrology.

**A-5. Manage to enhance and maintain edaphic conditions and structure.**

- Harvesting trees only when soils are frozen can help prevent soil compaction. This period will be shorter in a changing climate, making timing even more critical.

**A-6. Restore fire to ecosystems that previously depended on it.**

- Promoting fire-dependent ecosystems can help slow homogenization of ecosystems. Suitable habitat for oak species may substantially increase in northern Wisconsin forests in a warmer, drier climate, but fire suppression currently favors red maple (*Acer rubrum*). As another example, jack pine (*Pinus banksiana*) systems historically depended on fire and provide habitat for Kirtland’s warbler (*Dendroica kirtlandii*), an endangered species. Managers can promote diversity by encouraging oak species or jack pine through controlled burning.

**Response strategies**

**A-7. Increase the pool of genetic diversity when planting.**

- Managers could incorporate genotypes from areas south of northern Wisconsin that may be more adapted to future climates while keeping the same species composition.

**A-8. Preserve and improve connectivity across the landscape.**

- Connectivity can enable species to disperse on their own to more suitable habitats. Land managers could utilize existing mechanisms of land protection, such as *working forest conservation easements* or certification programs, to improve connectivity. *Research Natural Areas* could also be explored to set aside areas for connectivity.
- If managers pursue increased landscape connectivity, the potential increased risk of fire, transpiration losses from increased vegetation cover, and the spread of diseases and invasive species will also need to be considered.

**A-9. Assess the viability of current forest types.**

- The *Ecosystem Vulnerability Assessment and Synthesis* (Swanston et al. 2011) identified some forest types and ecosystem components vulnerable to climate change in northern Wisconsin, including lowland conifer and lowland hardwoods. Further assessments could help identify additional risks and vulnerabilities within these types.
- Managers and researchers could work together to assess the likelihood that current forest types will persist and the likelihood of management success. As one example, they could use models and monitoring to identify “trigger points” (i.e., thresholds where one forest type may make the transition to something else entirely).

**A-10. Position infrastructure to support response to climate change.**

- Instead of studying only biological infrastructure, managers may also need to examine physical infrastructure, such as buildings, roads, and bridges. For example, managers could increase culvert size to accommodate larger flows projected to occur early in the growing season. Appropriately-sized culverts are less susceptible to collapse, so would have less impact on ecosystems while reducing the likelihood of flooding.
- Scientists, land managers, and nursery managers could cooperatively examine nursery stock, especially for species that are more adapted to projected changes in climate. They could create infrastructure to increase the diversity of nursery stock and could select species that are currently growing south of the region but are likely to be suited to future climates in northern Wisconsin.

**A-11. Plan for disturbance.**

- Making a change after a disturbance might be easier than making a change in preparation for climate change. Thus it makes sense for managers to develop a response plan before an event such as a tornado or emerald ash borer infestation occurs. The objective is to get the public on board earlier to have options after disturbance.
- Managers can work with scientists to identify pests that are likely to increase due to climate change and integrate available information about pests and diseases into adaptive strategies.

**A-12. Identify newly suitable habitats.**

- In lowland hardwood systems, managers may want to encourage substitute species that are projected to increase under climate change and discourage regeneration of ash in harvested stands because of emerald ash borer.
- Climate change may improve habitat suitability of peatlands for lowland conifers if soils become drier from increased evaporation during summer months.

**Organizational capacity****A-13. Develop adaptive policies.**

- The uncertainty of climate change will require institutional flexibility. Policies will need to deliberately address and work with uncertainty within strategies and plans. Policy-makers may need to develop transitional plans or strategies because changes in climate will be erratic.
- On a local level, forest managers may need to plan for shorter winter logging seasons because the period when soils will be frozen may decrease with increasing temperature.

**A-14. Integrate upscaling and downscaling of information into adaptation strategies.**

- On-the-ground actions and observations at local levels need to feed back to broader policymaking and modeling efforts, and large-scale policies and model projections should be brought down to a local level, where effective decisions can be made on the ground.

**A-15. Increase information transfer with people in the surrounding landscape and manage social expectations.**

- Efforts to promote adaptation need to be expanded to incorporate public social and economic perspectives (i.e., how climate change may affect human behaviors and the forest products industry and vice versa). Public education programs are forums for informing citizens about the effects of climate change and for gathering information on the public's perspectives.
- There is a greater need for managers, scientists, and policy-makers to communicate with the public, but communication must go in both directions. Managers, scientists, and policy-makers will be more successful if they approach communication with the intent of engaging in dialogue. These groups could introduce the ideas of adaptive management and uncertainty in dialogue with public neighbors and industry.
- Planning could be more integrated among federal, state, county, tribal, and private forests and the timber industry. Public land managers, for example, could form partnerships with private landowners to assess climate change impacts and adaptation strategies.

**A-16. Create a prioritization process for implementing adaptation strategies.**

- Prioritization could be based on values such as critical habitat, the most vulnerable species or systems, or the most severe consequences. **Triage**, the prioritization process used in the

medical industry based on severity of condition, could be considered in the face of limited resources (Millar et al. 2007).

- Managers could import **risk management** or **hedging** theory into natural resource management to help prioritize adaptation strategies.

**A-17. Develop and utilize templates or tools to systematically assess climate change impacts and management activities.**

- For example, the Southern Research Station and the U.S. Forest Service Southern Region have developed a tool called TACCIMO (*Template for Assessing Climate Change Impacts and Management Options*) for National Forests in the southeastern United States and are beginning to include information for National Forests in the northeastern United States, such as the CNNEF.

## Additional Research Needs

**Understand what factors contribute to refugia (Strategy A-1).**

- The contribution of factors such as landform, aspect, soil characteristics, and climate could be examined.

**Increase research in plant genetics (Strategies A-3, A-7).**

- Scientists could assess genotypes resistant to current stressors (such as drought) or better adapted to altered climate regimes, and assess the genetic variation throughout the ranges for selected species.

**Develop better models to predict changing hydrologic regimes and potential effects of those changes (Strategy A-4).**

- Future models could consider effects of potential changes in evapotranspiration and groundwater on tree species, for example.

**Assess the quality or viability of ecosystem services from existing and novel forest types (Strategies A-9, A-12).**

- For example, research could be conducted to examine the effects of species substitutions on ecosystem services such as water quality and habitat.

**Find analogs (or identify the lack thereof) that represent a range of future climates in order to predict future species ranges (Strategies A-9, A-12).**

- Models for suitability of aquatic species that are somewhat similar to the modeling work from the Climate Change Atlas would be helpful.

**Implement species experiments to test model predictions on the ground (Strategies A-9, A-12).**

- Scientists could consider experiments where different species mixes or genotypes are planted.

**Determine the feedbacks of management and disturbance on climate (Strategy A-11).**

- Scientists could conduct research to better understand ecosystem response to novel combinations of disturbances that result from climate change and how they, in turn, may have effects on climate.

**Based on ecological assessments, undertake a social and economic assessment with the affected public to explore uncertainty and short-term and long-term consequences of climate change (Strategies A-13, A-14, A-15, A-16).**

- Public expectations of alternative futures could be identified.
- Trade-offs between social or economic values and long-term ecological sustainability or ecosystem services sustainability could be considered.
- More research on how to better communicate uncertainty to decisionmakers and the public may be needed.
- The limits, economic effects, and ways to overcome new challenges created by climate change, such as a shorter winter logging season, could be examined.

## Adaptation Breakout Session Summary

Overall, participants found that identifying adaptation strategies for forests in northern Wisconsin required clear goals and objectives. Participants identified several questions that need to be addressed before adaptation planning can begin in northern Wisconsin:

- **Why:** Why is the project being undertaken (i.e., what is the goal or objective)?
- **What:** What are you adapting (primarily human or ecological systems)? Are you trying to preserve species composition, forest type, ecosystem function, or socioeconomic benefits?
- **When:** Are your adaptation strategies addressing short-term (months-years) or long-term (decades) goals?

Despite not being fully able to answer these questions, participants were able to identify approaches that could be employed on the CNNF and the surrounding landscape using the conceptual framework provided by Joyce. Two overarching themes emerged. One theme was the need to adapt not only ecological systems but social systems as well, such as policies, public perceptions, and organizational structure. More research on these social issues combined with

greater engagement with multiple stakeholders will help address this need. A second theme was the need for more modeling to help support management decisions. Models could help predict hydrological changes, assess shifts in species ranges, identify climate feedbacks, and analyze decisions. A rapid feedback between on-the-ground actions and observations and modeling efforts would help increase the success and utility of these models.

## Breakout Session 2: Mitigation

### Conceptual Framework Talk: Forest Carbon Sequestration and Mitigation

**R**ichard Birdsey provided an overview of the concepts of forest carbon sequestration and greenhouse gas mitigation along with the preliminary results of the mitigation assessment conducted for northern Wisconsin (Appendix 2). He spoke on the role of public lands in forest carbon sequestration, and emphasized that mitigation strategies need to involve both public and private lands. National policies and programs are evolving to deal with the issue of carbon storage in forest management in public and private lands.

Phase I of the mitigation assessment focused on land-use change, bioenergy, the biological potential for forests to sequester carbon, and the transfer of carbon from forests to wood products. Preliminary results showed that housing development over the coming decades could lead to a decrease in forest land, thereby reducing carbon storage. Some of this decrease could be offset by **afforestation** projects if incentives were in place. Birdsey mentioned that wood bioenergy made up 4.6 percent of energy consumption in the State and had the potential to be expanded three-fold. The report also showed that forest carbon stocks in northern Wisconsin were mainly in soil and the greatest proportion of forest carbon stocks were in private lands. However, rates of carbon sequestration within private lands decreased in recent decades, possibly from greater harvesting,

aging forests, and increasing disturbances. Birdsey illustrated the biological potential with estimates from David Mladenoff's lab showing that if existing forests in northern Wisconsin were allowed to grow to maturity under historical disturbance regimes, the average annual gain in carbon stocks would increase from 1.5 to about 4.0 terragrams ( $10^{12}$  grams) carbon per year over the entire area for a few decades, until carbon stocks became typical of old-aged forests with slower growth rates (Fig. 7, Rhemtulla et al. 2009). He emphasized, however, that this high carbon scenario was unlikely to be consistent with current forest utilization and management practices.

### Mitigation Breakout Session Goals

The overall goal was to identify approaches and activities in northern Wisconsin forests that could contribute to enhanced mitigation of greenhouse gases.

Participants were asked the following specific questions:

1. How can our current knowledge be applied to carbon sequestration and greenhouse gas mitigation in northern Wisconsin forests?
2. What research activities could be carried out to help us fill in our current gaps in scientific understanding that impede progress in mitigating greenhouse gas emissions in northern Wisconsin?

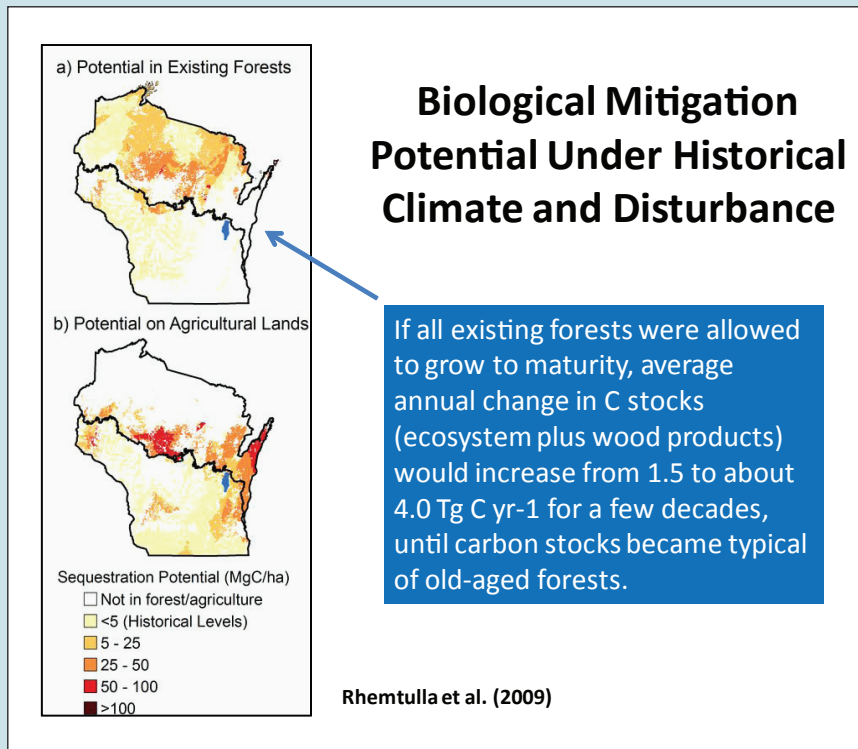


Figure 7.—Richard Birdsey showed work from David Mladenoff's lab indicating that there is biological potential to sequester additional carbon over the coming decades in northern Wisconsin, both by allowing existing forests to grow to maturity and by converting agricultural land to forest. (Illustration reproduced with permission of the National Academy of Sciences.)

Based on current knowledge of carbon cycling, bioenergy, and the effects of land use on carbon storage, participants identified strategies that could be examined in order to reduce greenhouse gas emissions or increase carbon storage in forests of northern Wisconsin. These strategies generally fell under the categories of enhanced sequestration or biomass energy and substitution. Participants also identified several research needs related to quantifying carbon sequestration and the benefits and tradeoffs of carbon management. It is important to note that these strategies have not been vetted across disciplines or scrutinized for viability and sustainability and could include some strategies that will ultimately be deemed unsuitable in many landscapes or for certain land uses. Strategies are numbered in no particular order. For each research need, the corresponding strategy numbers that they help address are listed in parentheses.

## Application of Current Knowledge

### Enhanced sequestration strategies

#### M-1. Evaluate practices that have mitigation potential and align with strategies for adaptation and general ecosystem health.

- Wetlands have the largest carbon stocks of all land cover types in northern Wisconsin. Restoration of wetlands can help increase carbon sequestration and can have adaptation benefits, such as creating refugia and restoring hydrologic function.
- Reducing disturbances to highly sensitive systems (a resistance adaptation strategy) can also decrease carbon loss from dead and downed wood.

- Planting trees adapted to a changing climate can increase carbon stocks more quickly than natural regeneration.
- Mitigation can be a co-product of forest management for biodiversity and sustainability. Forest conservation is a strategy for mitigation at a landscape scale.

**M-2. A carbon management strategy should include both wetlands and forests.**

- Managers may have to evaluate effects of a warmer, drier climate on the carbon balance in wetlands and change management strategies to maintain sequestration. Enhanced evapotranspiration in a warming climate may lead to natural afforestation of wetlands, potentially increasing carbon stocks in those areas. Conversely, changes in precipitation and summer drought could dry out peat and increase fire risk, thus potentially reducing carbon stocks.
- Wetlands have been off-limits to harvesting under some circumstances in the past due to policy and traditional practices. A wetlands management strategy may need to be employed. Industry may exert pressure in the future to manage these lands and enhance their mitigation potential, but whether management in peatlands would truly be beneficial needs to be examined.

**M-3. Consider extending northern hardwood rotation periods for carbon storage, but be mindful of carbon sequestration rates among various age classes.**

- Extension of rotation periods in northern hardwoods is already being considered on the CNNF to increase carbon sequestration. The tradeoff is that storage in the long term may not increase as much as in the short term due to declining sequestration rates in older trees.
- Longer rotations nationally may mean importing more wood from international sources, so considerations of **leakage** need to be kept in mind as well.

**M-4. Consider increasing stocking, but be mindful of increased susceptibility to fire.**

- The Winrock report (Brown et al. 2008), which examined carbon storage in Wisconsin and recommended increased stocking, was unable to examine practices occurring at finer resolutions. Some mitigation suggestions in the report entail potentially greater risks, such as higher susceptibility in fire-prone systems when density is increased.

**M-5. A carbon storage and sequestration strategy requires consideration of age structure and composition at multiple temporal and spatial scales.**

- Time horizon is important. Some managers may tend to think about mitigation over a shorter time horizon (years) and on small spatial scales (a particular stand), but all strategies should be considered over long-term time horizons (decades) and on large spatial scales (entire forests, states, ecoregions).



**M-6. Management strategies to increase carbon sequestration must be made in light of other values.**

- Tools like the *Forest Vegetation Simulator* can help evaluate the effects of management actions on carbon sequestration and how these effects compare with other management goals. It is acceptable to not choose an action with the greatest sequestration potential if another objective is deemed more important.

**M-7. A carbon sequestration strategy requires consideration of the role of both public and private lands.**

- Counties and private landowners often want to see someone else try carbon markets first before they invest time, financial resources, and effort in them. The CNNF could be a demonstration area for this type of activity to show whether or how participation in a carbon market could work, stopping short of selling credits. However, the Forest Service's mission and goals cannot always be translated to private lands.
- The state and county may focus on increasing sequestration while the CNNF has a greater potential to maintain storage in existing forests. State and county leaders would then seek to enhance sequestration on neighboring private lands, and the CNNF would focus on maintaining storage. Ways the CNNF can develop incentives for these strategies need to be examined.

- Land managers on the CNNF can help limit deforestation and promote reforestation on the landscape scale by working with state, local, and county entities to identify areas most at risk. State forest assessments and strategies developed in response to the 2008 Farm Bill can identify those lands that are most at risk to a variety of threats or most beneficial to their states and communities. To set priorities for expanding the capacity of the CNNF to focus on the most beneficial and at-risk lands using the Wisconsin state assessment, the CNNF could collaborate with the Forest Service's State and Private Forestry.
- Management decisions on private lands are often driven by economics, and carbon markets can be incentives to encourage carbon management. **Additionality** (whether actions taken to increase sequestration are beyond business-as-usual) must be considered when devising incentives for mitigation activities. Current voluntary markets are working to ensure all enrolled forestry programs are additional and not just claiming credit for routine management regimes that do not increase overall carbon storage.
- Private landowners can utilize existing national programs such as the *Forest Legacy Program* and the *Forest Stewardship Program* to maintain forested areas. Programs like these are intended to keep blocks of forest intact. The Forest Legacy Program's efforts could be combined with public land trusts to leverage effects. It

must be remembered that the Forest Legacy easements do not allow private landowners to retain rights to forest carbon sequestration credits. The Forest Stewardship Program could be utilized to target those private lands that may not be likely candidates for conservation easements.

- Forest managers could enhance working relationships with tribes. Managers can utilize existing cooperative agreements with tribes for harvests and explore opportunities for cooperative research. They should consult with tribes about treaty-protected harvest rights before making changes.

**M-8. Identify high-priority areas for sequestration activities.**

- Managers could break down the landscape into three main categories according to how the areas are utilized, such as extended rotation/management areas, production areas, and passive areas.

### **Bioenergy and Substitution Strategies**

**M-9. Be aware of the limitations of bioenergy.**

- Recent scientific evidence suggests that the benefits of bioenergy in reducing greenhouse gas emissions may not be as high as previously suggested. Decisions made related to bioenergy in northern Wisconsin should be made in light of the latest scientific evidence.

**M-10. Consider marginal agricultural lands and alternative species mixes for bioenergy production.**

- Native forests may not be the best option for bioenergy production, so alternatives can be examined for short-rotation intensive management for bioenergy. For example, a paper mill in Minnesota has converted from use of aspen (*Populus tremuloides*) to hybrid poplar (*Populus* spp.). Leasing marginal farmland and converting to poplar is a potential option.
- The U.S. Department of Agriculture (USDA) has several sets of authorities for business incubation. The USDA and the Forest Service could focus on some areas as pilot areas. The USDA Farm Service Agency, for example, has a biomass crop assistance program that could be utilized. This approach is consistent with the Secretary of Agriculture's goal of "one USDA."

**M-11. Monitor where demand for bioenergy is likely to increase.**

- The radius of influence of a biomass power generation facility could be considered and Best Management Practices (BMP's) should be employed for biomass facilities.

## Additional Research Needs

### Increase understanding of management effects on belowground processes and soil carbon sequestration effects (Strategy M-1).

- For example, little is known about the longer-term impacts of prescribed fire on belowground carbon sequestration and restoration. If managers are interested in influencing future forest species composition using prescribed burning, then it would be helpful to better understand belowground processes.

### Address the role of other greenhouse gases such as methane and nitrous oxide and non-forest landscapes such as wetlands (Strategy M-2).

- Although most emphasis has been placed on forests and carbon dioxide, wetlands store large amounts of carbon and release methane and nitrous oxide. Scientists could consider long-term research and monitoring of carbon and greenhouse gases in wetlands. *AmeriFlux* and the *National Ecological Observatory Network* (NEON) are examples of research and monitoring programs that could potentially be utilized. Mechanisms to set up long-term ecological research sites and funding sources could be explored.

### Mine data on carbon and management activities from the past to direct future management of carbon (Strategies M-3, M-4, M-5).

- The CNNF and other researchers have collected a lot of data on past management activities and carbon storage that could be useful, but these data need to be analyzed, organized, and automated to help in research, modeling, and decisionmaking.

### Conduct research on carbon mitigation across ownership boundaries (Strategy M-7).

- Birdsey reported that carbon sequestration has declined recently on private lands. Research to validate and understand the drivers behind this reduction would be beneficial.
- Social science research on private landowners' willingness to participate in carbon markets and other incentives would also help in our understanding of incentives for sequestration.

### Provide information to public managers and private landowners interested in markets on how much sequestration they can obtain under different management scenarios (Strategy M-7).

- The CNNF could provide a place for studies that provide these values and validate models.

### Assess the ecological consequences of carbon mitigation, with a particular emphasis on tradeoffs related to biomass energy and other resources (Strategies M-9, M-10).

- Carbon management decisions can also affect water resources. Research could examine how decisions related to carbon affect the water balance, water quality, and lake-related ecosystem services in northern Wisconsin.
- Species used for bioenergy production, such as aspen, require certain levels of nutrients. Nutrient budgets and nutrient cycling could be studied where bioenergy production is a goal.

### Conduct an economic analysis of ways to provide incentives for activities across the landscape (Strategies M-6, M-7, M-11).

- Life-cycle analysis tools can be used to make a case for the economic value of local wood products.

**Develop a research consortium to evaluate different strategies for carbon management under a changing climate (All strategies).**

- A research consortium among scientists and managers from the CNNF and other lands could be initiated. The consortium could set up sequestration experimental areas and compare over time the forest type and species projected to do best under climate change with forest types and species that are currently best for sequestration. Results from the study could be used to select high-priority areas for sequestration and long-term monitoring.

**Mitigation Breakout Session Summary**

Overall, participants were cautious about the potential for the CNNF and the surrounding landscape of northern Wisconsin to reduce greenhouse gas emissions and enhance carbon sequestration through forest management. Participants agreed that mitigation strategies would not be effective in the long term unless they were carried out in conjunction with adaptation strategies. Results from the mitigation assessment and Birdsey's presentation showed that the greatest potential for enhanced sequestration lies outside of the CNNF's boundaries. Therefore, mitigation strategies would require collaborative relationships between public and private landowners and a greater understanding of incentives. Participants also identified several knowledge gaps that need to be addressed, most notably the role of soils and wetlands in carbon storage and the ecological tradeoffs of managing for carbon sequestration and bioenergy production.

## Breakout Session 3: Monitoring

### Conceptual Framework Talk: Monitoring and Climate Change

**D**avid Cleland provided a national perspective on the status and needs of climate change monitoring. He emphasized that national assessments have found that existing monitoring programs were insufficient to detect the impacts of climate change and the effectiveness of adaptation and mitigation actions (Backlund et al. 2008). Other national assessments have emphasized the need for a hierarchical approach to monitoring using spatial hierarchies such as the Forest Service's ecological

classification system (Fagre et al. 2009). He then gave a brief review of emerging monitoring programs that are attempting to address monitoring needs for climate change, such as the U.S. Geological Survey's LandCarbon<sup>5</sup> project and the U.S. Fish and Wildlife Service's Landscape Conservation Cooperatives.<sup>6</sup> Finally, Cleland used an example (Fig. 8) to illustrate the need for an integrated hierarchical approach.

<sup>5</sup>More information can be found at: [http://www.usgs.gov/global\\_change/carbon/methodology.asp](http://www.usgs.gov/global_change/carbon/methodology.asp)

<sup>6</sup>More information can be found at: <http://www.fws.gov/science/SHC/lcc.html>

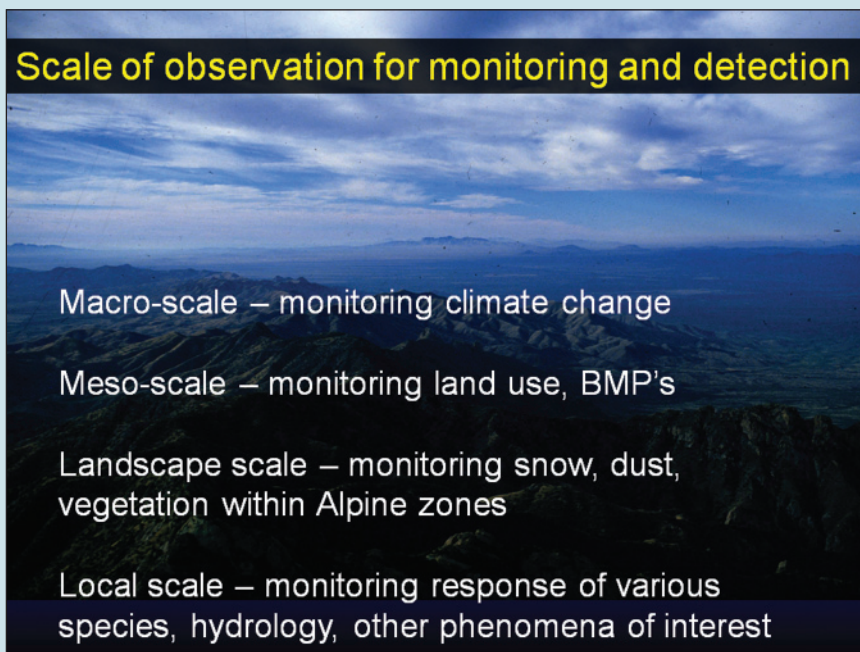


Figure 8.—David Cleland emphasized the need to take a hierarchical approach to monitoring climate change, its effects, and the effectiveness of management actions. (Illustration by David Cleland, U.S. Forest Service.)

## Monitoring Breakout Session Goals

The overall goal of the monitoring breakout session was to explore ways to monitor climate change impacts and the effectiveness of adaptation and mitigation strategies for forests in northern Wisconsin.

Participants were asked the following specific questions related to monitoring:

1. How can we monitor climate change impacts on northern Wisconsin forests?
2. How can we monitor the effectiveness of our adaptation and mitigation actions in northern Wisconsin forests?

Participants identified several strategies and approaches to increase monitoring of climate change and its impacts on species and ecosystems in northern Wisconsin. They also offered insight into how to approach effectiveness monitoring for adaptation and mitigation strategies. It is important to note that these strategies have not been vetted across disciplines or scrutinized for viability and sustainability and could include some strategies that will ultimately be deemed unsuitable in many landscapes or for particular land uses.

## Monitoring Impacts

**Develop a network of existing monitoring efforts.**

- An attempt could be made to work with the existing monitoring infrastructure first, then add or improve. The current monitoring on National Forests is not integrated into a network. The CNNF could be a model for how to integrate monitoring activities.

- The Forest Service could potentially expand the Forest Inventory and Analysis (FIA) network to regularly collect other types of data such as changes in the understory. FIA already has standardized protocols for selecting sites and collecting data at two different scales. States currently can pay FIA to intensify data collection spatially and temporally. Northern Wisconsin could be expanded as a trial, but there is a legal requirement that FIA not disclose exact plot coordinates, which could present potential problems with some analyses.
- The CNNF could become part of a national citizen-scientist monitoring network. One example of such a network, the *National Phenology Network*, looks at climate change effects on growing seasons and flowering dates.
- The impacts of climate change are important not only for vegetation but also for water. The CNNF could be part of a hydrologic network such as the *USGS Stream Gauge Network*.
- Coarse-scale monitoring (such as MODIS-derived phenology monitoring from the *Eastern Forest Environmental Threat Assessment Center*) can be tiered to local on-the-ground monitoring.

**Monitor species and ecosystem processes that are sensitive to climate change and could serve as early indicators, keeping cost in mind.**

- For trees, managers could monitor early regeneration success or failure (<6 years after harvest), tree mortality and dieback in crowns, or cumulative effects of disturbance agents.
- For animals, managers could target species sensitive to climate change, such as trout,

salamanders, or aquatic insects. They could measure the number of life cycles and growing season length for insects and their host plants. Small mammals with shorter life spans and more mobile species that can move away from undesirable conditions may also be early indicators.

- Soil processes such as respiration, fluxes of trace gases, mineralization, and nitrification could be early indicators, but are expensive to monitor. As a “model forest,” the CNNF might be a place to do this more high-cost monitoring.
- Phenological indicators such as leaf-out, flowering, last leaf, bird migration, and ice-duration on lakes can be monitored relatively easily and are clear climate change indicators.
- Class 1 and 2 trout streams will be sensitive to 1 to 2 °C increases in stream temperature and could serve as early indicators.
- Water levels of the Great Lakes and inland lakes can also be monitored easily, but direct links to climate change can be confounded by other factors.
- Social and economic indicators could include tourism, public opinions, and social and economic data from the Census Bureau.
- Disturbance agents such as insects, wildfire, and drought will have synergistic effects with climate change and should be monitored as well.
- Alternative ways to measure temperature could also be considered. For example, in the western United States, FIA is installing inexpensive temperature sensors on trees. Someone needs to return only once a year to collect the data.
- Information to help in understanding why northern Wisconsin is getting drier could also be collected.

#### **Consider a research-management partnership.**

- People in leadership roles may need to reassess where researchers are located and how they are rewarded. For example, researchers and managers being co-located can increase collaboration. Those in leadership roles also could assess how managers might better articulate their uncertainties as research questions so that research studies are more applicable to management. Managers’ questions are often time-sensitive and researchers are not often rewarded for applying their research to management. Leadership will have to assess ways to eliminate these barriers. The *Wisconsin Initiative on Climate Change Impacts* (WICCI) wildlife group and Forest Service experimental forests provide potential examples for implementing these approaches.
- Science-manager partnerships work better where specific questions are identified and forest managers are on board with trying to answer those questions.
- If the CNNF is treated as a “living laboratory,” it needs to be approached with the experimental forest model (i.e., a place that supports long-term research on management issues). One working example is the *Ameriflux Chequamegon Ecosystem–Atmosphere Study* (ChEAS) on the CNNF.

#### **Monitor climate directly.**

- There is a need for higher-resolution weather data and a higher density of weather stations. Currently, the number of weather stations across the nation is going down, and the CNNF might need to fill in those gaps for its area.

**The CNNF could develop a research-monitoring team to help the Forest better integrate monitoring data into management and appoint a research liaison.**

- A science-manager partnership needs to become a monitoring partnership. A research and monitoring task force could help interpret data that have been gathered and increase understanding. The task force could meet with managers and see what the data mean and what appropriate actions should be taken.

**Increase the spatial and temporal scale of monitoring in key areas on the landscape.**

- Managers and scientists could target monitoring to low-diversity and vulnerable ecosystems such as forest types identified in the *Ecosystem Vulnerability Assessment and Synthesis* (Swanston et al. 2011).
- Managers and scientists could begin to monitor particular species range expansions or contractions, by focusing monitoring plots on species near and just outside their approximate northern or southern limits.
- Monitoring programs could use spatial hierarchies, such as those created by geologic landforms, to stratify landscapes into meaningful analysis units.

**Ensure that organizations complement one another's monitoring efforts.**

- Information needs to be accessible, and there needs to be better communication about the range of research and management activities occurring that could utilize monitoring information. A forum is needed for knowing what is out there. The National Park Service does a good job of tying together some of these

networks through the *Great Lakes Inventory and Monitoring Network*. In the Forest Service, someone oversees the research that is occurring in *Research Natural Areas*. It would be helpful to have oversight for research on the CNNF as well.

- The legal, mission-related, evaluation, and institutional barriers to working in an integrated, inter-agency network need to be addressed. If research and management are to be coordinated and if organizations are going to complement one another's work, then barriers to working with partners must be reduced.

**Outline monitoring goals and protocols well before monitoring begins.**

- For example, the National Park Service's *Great Lakes Inventory and Monitoring Network* establishes clear goals and protocols that ensure standardization and quality.

## Monitoring the Effectiveness of Adaptation and Mitigation Strategies

**Identify cost-effective indicators or suites of indicators to streamline effectiveness monitoring.**

- Those conducting monitoring can re-evaluate the list of indicators periodically. Unknowns will arise, some indicators may no longer exist, our knowledge will improve, and we will learn from experience.
- Sometimes suites of indicators will indicate changes better than a single indicator.
- The CNNF could look at what partners have identified as key indicators and adopt those indicators for monitoring on its lands.



- Scientists and managers could use ecosystem models to assess current conditions, identify gaps where measurements and monitoring are necessary, project into the future, and monitor outcomes to assess model performance.

**Consider conducting a purposeful outside review of Forest Service monitoring protocols.**

- An outside review can increase transparency and help identify potential pitfalls and shortcomings in a monitoring protocol.

**Capitalize on collaboration and partnerships with other organizations.**

- Collaboration can increase the intensity and extent of data collection and increase cost-effectiveness. The CNNF could consider enlisting volunteers or joining with other agencies, states, and tribes for monitoring work. The CNNF could sponsor an annual monitoring network meeting to coordinate monitoring efforts.
- “Effectiveness” and success can be defined at the landscape scale, not just on the CNNF. The goal is a healthy landscape, not just a healthy National Forest. A measure of success is the degree to which the Forest Service collaborates with states, WICCI, and other partners and the level of interest and investigations on the CNNF by the scientific community.
- The Wisconsin Statewide Forest Assessment and Strategy<sup>7</sup> can help set climate change monitoring goals.

**Set mitigation goals and monitor carbon storage.**

- It is also important to monitor other impacts over the long term and trade-offs with other ecosystem services. Some indirect effects will unfold over many years.
- Managers and scientists could utilize carbon calculators that also take into account the entire investment of carbon into mitigation efforts such as electricity, transportation, and cost of fertilization.

**Use monitoring data to influence institutional behavior.**

- Monitoring the changing social context is also important. Social scientists can assess the public’s knowledge and perceptions of climate change, adaptation, and mitigation. This information can then be used to adjust behaviors in the context of shared values.

**Close the loop on the adaptive management circle: lessons from effectiveness monitoring should feed back into management actions.**

- The feedback arrow in the adaptive management cycle is often weak (Fig. 9). For example, The Nature Conservancy does not do much monitoring because data from monitoring often do not influence management decisions. However, the Great Lakes Inventory and Monitoring Network organized by the National Park Service is doing a good job of bringing researchers and managers together and may serve as a model.

<sup>7</sup>More information can be found at: <http://dnr.wi.gov/forestry/assessment/strategy/overview.htm>

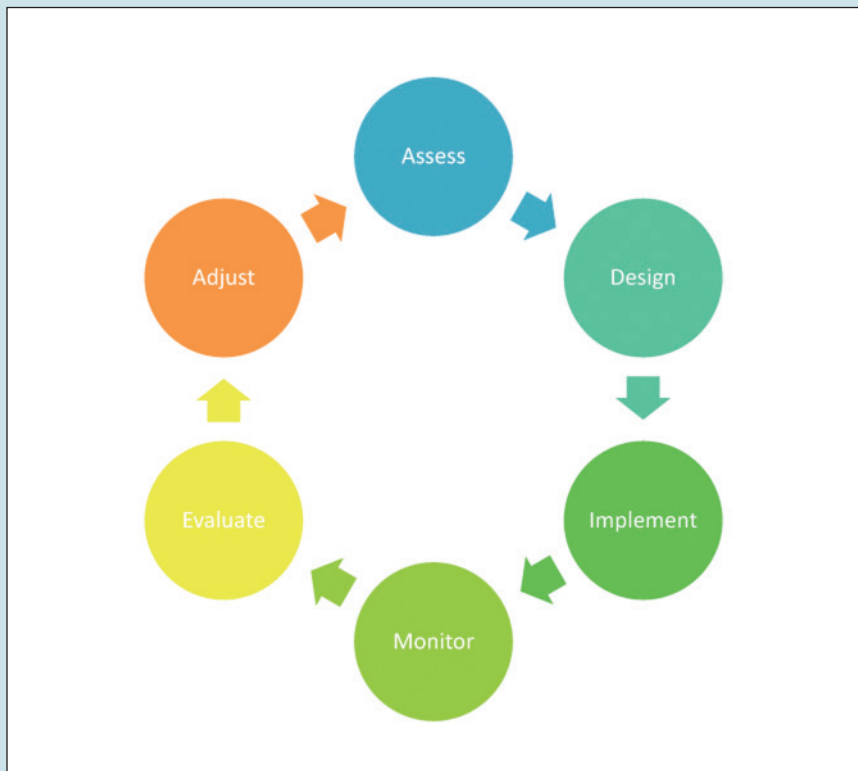


Figure 9.—Workshop participants discussed the adaptive management cycle, illustrated here. The monitoring step is often missing or not as strong as it could be, weakening the entire cycle. (Illustration by Leslie Brandt, U.S. Forest Service.)

- The CNNF may need to adjust how monitoring feeds into management. This is the perfect time for the CNNF to ask for resources to close the research-management gap. The Forest is currently at the midpoint of its Forest Plan. In 3 to 5 years, climate change-related information could have an effect on future monitoring efforts and feed back to the Plan revision.

### Monitoring Breakout Session Summary

Some overarching themes emerged from the breakout session, and reinforced the points raised in Cleland's talk on monitoring impacts and effectiveness of management actions. Current monitoring efforts in northern Wisconsin were

deemed insufficient to detect impacts and were not perceived as well-integrated with each other. Many factors confound the impact of climate change and will interfere with land managers' ability to detect climate change impacts. Participants said that managers need to decide what questions they want to answer and to determine whether they are monitoring the right things in the right way to answer those questions. For example, if the management community of northern Wisconsin set priorities, collaborated, utilized citizen scientists, and identified key indicators that were not expensive to monitor, then costs would be reduced. Finally, participants agreed it would be difficult to monitor the effectiveness of adaptation and mitigation strategies until managers and researchers establish what those strategies are.

# Workshop Themes and Conclusions

General strategies identified in the workshop were similar to those described previously in the literature, but specific approaches to these strategies reflected the unique aspects of the northern Wisconsin landscape. For example, the need to increase connectivity to allow migration to more suitable habitats is one of the most frequently mentioned strategies in the adaptation literature (Galatowitsch et al. 2009, Heller and Zavaleta 2009), but participants were able to suggest a few specific approaches that could work in northern Wisconsin to achieve that goal. Likewise, increased forest stocking and afforestation have been previously identified as broad strategies in the mitigation literature (Fissore et al. 2009). Participants discussed the difference in potential for afforestation between private and public lands in Wisconsin, and were able to propose incentives for private landowners to increase forested land.

Outcomes from this workshop emphasized the importance of a place-based response to climate change. Unlike many places, northern Wisconsin is still supported economically by an active timber industry. Compared to many western National Forests, the CNNF is smaller and more heavily interspersed with private lands. Wisconsin also has a large concentration of wetlands that participants agreed should be integrated into mitigation and adaptation decisions because they are both large carbon sinks and potential refugia. Past glaciation and land management have altered hydrology and species composition in northern Wisconsin and continue to leave a footprint to

this day. Understanding how these processes have contributed to current ecosystem and species distributions was seen as critical. Considering the variety of landowners surrounding the CNNF, strategies devised for responding to climate change on the CNNF must be made in concert with its neighbors.

Several major themes emerged from the workshop:

1. In order to be effective at responding to climate change, forest managers in northern Wisconsin need to establish clear goals for adaptation, mitigation, and monitoring and make sure these are articulated and integrated. Ecological, social, and economic goals will need to be weighed, and mitigation will have to be balanced with adaptation.
2. Land managers and scientists alike need to remember that all management decisions will ultimately be made in a social and economic context. While taking an adaptation or mitigation action may make sense from an ecological standpoint, it has little chance of success if it is not favorable economically or socially.
3. Change in the way forests are managed in response to climate change requires a large investment of time and resources from a diverse group of experts and stakeholders. A National Forest or group of scientists cannot undertake such change in isolation because no single entity encompasses the breadth of perspectives and values of the larger community across the landscape.

4. Science and management need to be better integrated. Institutional barriers, time lags, lack of a common language, and different incentive structures will continue to impede cooperation and coordination until changes are made institutionally.

Participants at the workshop suggested the forests of northern Wisconsin have a potential to serve as a model adaptive management landscape. This model landscape can bring strong research capacity to bear when management decisions

are made in the face of climate change. A stronger incorporation of a research element into management and vice-versa will help ensure that we learn from monitoring and management, while delivering products that are tailored to suit specific needs. Although many climate change strategies identified in this workshop will be influenced by place, this concept of integration of science and management can be replicated widely and help forests be better prepared for a rapidly changing climate.

# Glossary

**adaptation strategies**—Actions taken to help a system to resist or accommodate climate change.

**adaptive capacity**—The general ability of institutions, systems, and individuals to moderate the risks of climate change, or to realize benefits, through changes in their characteristics or behavior. Adaptive capacity can be an inherent property or it could have been developed as a result of previous policy, planning, or design decisions.

**adaptive management**—An iterative approach that treats on-the-ground management actions and policies as hypotheses, which are tested and monitored (Holling 1978).

**additionality**—A term used in carbon markets to refer to the concept that in order for an action to qualify as a carbon offset, it must be in addition to “business as usual.”

**afforestation**—The act of planting trees or tree seeds on land that has not been forested recently.

**debiasing**—A technique that removes regional biases from models where they tend to over- or underestimate precipitation or temperature.

**downscaling**—A method for obtaining high-resolution climate or climate change information from relatively coarse-resolution global climate models. Downscaling involves examining the statistical relationship between past climate data and on-the-ground measurements.

**edaphic conditions**—Characteristics of the soil (for example, the drainage, texture, or soil chemical properties, such as the pH).

**effectiveness monitoring**—Evaluating outcomes from on-the-ground management activities. Goals for effectiveness monitoring could be to gauge an activity’s ability to increase carbon storage, reduce stressors, enhance resilience, or conserve species.

**emission avoidance**—Aims to reduce the loss of forest land to other uses.

**enhanced sequestration**—Efforts to increase carbon stocks in forests and wood products.

**evapotranspiration**—The sum of evaporation and plant transpiration from the Earth’s land surface to the atmosphere.

**hedging**—The act of spreading risk by investing in multiple strategies (form of risk management).

**leakage**—Condition occurring when policies or actions to reduce greenhouse gas emissions in one place result in an increase in greenhouse gas emissions elsewhere.

**mitigation**—In the context of climate change, a human intervention to reduce the sources or enhance the sinks of greenhouse gases.

**monitoring**—The collection of information over time, generally on a sample basis by measuring change in an indicator or variable, to determine the effects of resource management treatments in the long term.

**realignment**—The process of tuning ecosystems or habitats to present and anticipated future conditions in such a way that they can respond adaptively to ongoing change.

**refugia**—Locations and habitats that support populations of organisms that are limited to small fragments of their previous geographic range.

**resilience**—Adaptation option intended to accommodate some degree of change, but allow for a return to prior conditions after a disturbance, either naturally or through management.

**resistance**—Adaptation option intended to improve the defenses of a forest against anticipated changes or directly defend the forest against disturbance in order to maintain relatively unchanged conditions.

**response**—An adaptation option to accommodate change and enable ecosystems to adaptively respond to changing and new conditions.

**risk management**—The identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities.

**substitution**—Using forest products in place of more greenhouse-gas intensive products, especially the use of wood for bioenergy.

**systematic monitoring**—The establishment of monitoring locations across large areas, with monitoring stations often located in an established grid of various resolutions. Examples of systematic monitoring include the Forest Inventory and Analysis program, the U.S. Geological Survey National Stream Gauge Network, and the Natural Resources Conservation Service’s Natural Resource Inventory.

**targeted monitoring**—Assessing particular areas based on specific objectives, using measurements or indicators related to that objective. Examples of targeted monitoring include population monitoring of endangered species, detecting changes in hydrology in watersheds, and monitoring outbreaks of insects and diseases.

**tension zone**—A transitional area between two distinctive areas of floristic composition that is influenced by climatic or geologic factors, creating an area where flora from the two areas overlaps.

**triage**—In the context of forest management, a systematic process to sort management situations into categories according to urgency, sensitivity, and capacity of available resources to achieve desired goals.

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# Appendix 1: Climate Change Response Framework Project Documents

## Climate Change Response Framework Project Summary

This one-page briefing document provides an overview of the goals and objectives of the Climate Change Response Framework project and highlights the four main components of the Framework development process.

[www.nrs.fs.fed.us/niacs/climate/framework/](http://www.nrs.fs.fed.us/niacs/climate/framework/)

## Ecosystem Vulnerability Assessment and Synthesis

This document evaluates key ecosystem vulnerabilities in northern Wisconsin under a range of future climates using existing models and information. Later versions may provide additional information on social, environmental, and economic implications.

<http://www.nrs.fs.fed.us/pubs/38255>

## Mitigation Assessment

This draft document evaluates options to increase carbon stocks in forests and wood products, increase the use of wood for bioenergy, and engage in greenhouse gas markets and registries. Later versions of this document may integrate future forecasts of the Vulnerability Assessment to address the potential viability of mitigation options under potential changes in climates and ecosystems.

[http://www.nrs.fs.fed.us/niacs/climate/Wisconsin/draft\\_docs/docs/Full\\_CNNF\\_Mitigation\\_Assessment\\_Draft.pdf](http://www.nrs.fs.fed.us/niacs/climate/Wisconsin/draft_docs/docs/Full_CNNF_Mitigation_Assessment_Draft.pdf)

## Shared Landscape Initiative Workshop Summary

The Shared Landscapes Initiative is a means to ensure that products from the CCRF project are actively shared and discussed with both landowners and the public in northern Wisconsin. A Shared Landscapes Initiative workshop was held February 24-25, 2010 in Rhinelander, WI.

[www.nrs.fs.fed.us/niacs/climate/northwoods/sli/](http://www.nrs.fs.fed.us/niacs/climate/northwoods/sli/)

## **Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers**

This draft document provides perspectives, information, and tools to help managers incorporate climate change considerations into management and adapt forest ecosystems in northern Wisconsin to a changing climate.

*[http://www.nrs.fs.fed.us/niacs/climate/Wisconsin/draft\\_docs/docs/FAR\\_Final\\_Draft.pdf](http://www.nrs.fs.fed.us/niacs/climate/Wisconsin/draft_docs/docs/FAR_Final_Draft.pdf)*

## **Lessons Learned from the Climate Change Response Framework Project in Northern Wisconsin**

This document records the processes, products, and lessons learned from the Climate Change Response Framework Project to provide information and inspiration to others working in the arenas of climate change assessment and adaptation response. This document features major lessons and observations, as well as more subtle considerations and suggestions for moving forward on similar projects.

*[http://www.nrs.fs.fed.us/niacs/local-resources/docs/LESSONS\\_LEARNED\\_from\\_the\\_CCRFP.pdf](http://www.nrs.fs.fed.us/niacs/local-resources/docs/LESSONS_LEARNED_from_the_CCRFP.pdf)*

## Appendix 2: List of Participants

<b>Participant</b>	<b>Organization</b>		
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Matt Dallman	The Nature Conservancy	Danny Lee	Eastern Forest Environmental Threat Assessment Center
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Degi Dugarjav	University of Wisconsin—Madison	Karl Martin	Wisconsin Department of Natural Resources
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Megan Matonis	U.S. Forest Service, Policy Analysis	Elizabeth Reinhardt	U.S. Forest Service, Policy Analysis
Steve McNulty	U.S. Forest Service, Southern Research Station	Suzanne Sanders	National Park Service, Great Lakes Network Office
Nick Miller	The Nature Conservancy	Tom Schmidt	U.S. Forest Service, Northern Research Station
David Mladenoff	University of Wisconsin—Madison	Matt St. Pierre	Chequamegon-Nicolet National Forest
Knute Nadelhoffer	University of Michigan	Susan Stewart	U.S. Forest Service, Northern Research Station
Linda Nagel	Michigan Technological University	Brian Sturtevant	U.S. Forest Service, Northern Research Station
Tia Nelson	Board of Commissioners of Public Lands	Chris Swanston	Northern Institute of Applied Climate Science/U.S. Forest Service
Michael Notaro	University of Wisconsin—Madison Center for Climatic Research	Barbara Tormoehlen	U.S. Forest Service, Northeastern Area
Greg Nowacki	U.S. Forest Service, Eastern Region	Phil Townsend	University of Wisconsin—Madison
Eunice Padley	Wisconsin Department of Natural Resources	Don Waller	University of Wisconsin—Madison
Brian Palik	U.S. Forest Service, Northern Research Station	Jack Williams	University of Wisconsin—Madison
Linda Parker	Chequamegon-Nicolet National Forest	Weimin Xi	University of Wisconsin—Madison
Mike Prouty	Great Lakes Forest Alliance		
Volker Radeloff	University of Wisconsin—Madison		

## Appendix 3: Biographies of Speakers

**Chris Swanston** is the Director of the Northern Institute of Applied Climate Science (NIACS) and a Research Ecologist for the U.S. Forest Service's Northern Research Station. His scientific research focuses on the processes that control organic carbon dynamics in forest soils. Since becoming director of NIACS in 2008, Swanston has taken the lead on developing educational outreach and technology transfer products and services to assist the National Forest System in responding to climate change. He is the principle investigator on the Chequamegon-Nicolet Climate Change Response Framework Project. Swanston holds a B.S. in Forest Ecology and Soils from Humboldt State University and a M.S. and Ph.D. in Forest Science from Oregon State University.

**David Cleaves** is the Climate Change Advisor to the Chief of the Forest Service. Prior to his appointment, Cleaves served as Associate Deputy Chief of Research and Development for the Forest Service. He has served in many capacities throughout his Forest Service career. He was Director of the Rocky Mountain Research Station; staff director for all national research programs in economics, forest products, social science, recreation and tourism, urban forestry, and science education; the National Program Leader for Fire Systems Research; and research project leader in fire economics and management. Prior to joining the Forest Service, Cleaves was a professor at Oregon State University. Cleaves is the author of numerous publications in the field of decision science and risk analysis. He has a B.S. and M.S.

from Michigan State University and a Ph.D. in Economics from Texas A&M University.

**Kent Connaughton** was Regional Forester of the Forest Service's Eastern Region from 2008 to 2011. In that capacity, Connaughton oversaw 14 National Forests and the country's only National Tallgrass Prairie. Connaughton came to the Eastern Region from the Forest Service's Washington Office, where he served as Associate Deputy Chief for State and Private Forestry. Connaughton began his career at the Forest Service's Pacific Northwest Research Station as a forest economics researcher. Over the course of his 30-year career in the Forest Service, his assignments included Forest Supervisor on the Lassen National Forest in California, and Deputy Regional Forester for State and Private Forestry in the Pacific Southwest Region. Connaughton holds a B.A. from Stanford University, a Master of Forestry from Oregon State University, and a Ph.D. from the University of California, Berkeley. He was elected fellow of the Society of American Foresters in 1991.

**Thomas Schmidt** is the Assistant Director of Research for the Forest Service's Northern Research Station. Prior to his current position, Schmidt held positions in the Forest Service as Assistant Director for Information Management and Program Delivery, Project Leader in Ecology and Management of Riparian/Aquatic Ecosystems, and Research Scientist in Forest Inventory and Analysis. Outside the Forest Service, Schmidt has held positions at Utah State University,



the University of Nebraska, and the Missouri Department of Natural Resources, and as a Peace Corps volunteer. He has a B.S. in Forest Management and M.S. in Forestry from the University of Missouri and a Ph.D. in Agronomy-Range Ecology from the University of Nebraska.

**Michael Notaro** is an associate scientist at the Center for Climatic Research at the University of Wisconsin—Madison. He is also a member of the Climate Working Group of the Wisconsin Initiative on Climate Change Impacts. Notaro's research interests include global and regional climate modeling and vegetation-climate interactions. He holds a B.S., M.S., and Ph.D. in Atmospheric Science from the State University of New York at Albany.

**Louis Iverson** is a Research Landscape Ecologist with the Forest Service's Northern Research Station in Delaware, OH, and Adjunct Professor with the School of Natural Resources at the Ohio State University. He has served in many offices, including president of the U.S. Chapter of the International Association for Landscape Ecology (IALE) and vice president of the international governing body of IALE. Iverson is the book review editor for *Landscape Ecology* and was named Distinguished Landscape Ecologist for US-IALE in 2002. Prior to his current position, he worked for the Illinois Natural History Survey and was a Fulbright Scholar to the University of York, England. Iverson's current research interests include understanding the potential impacts of climate change on tree species, spatially modeling risk from the invasive emerald ash borer, using prescribed fire and thinning in restoring oak communities, and investigating ecology's role in disaster and poverty alleviation. Iverson received his Ph.D. from the University of North Dakota.

**David J. Mladenoff** is the Beers-Bascom Professor of Conservation in the Department of Forest and Wildlife Ecology at the University of Wisconsin—Madison. Mladenoff has held positions in The Nature Conservancy as western region Science and Stewardship Director, and the University of Minnesota Natural Resources Research Institute in Duluth. At the University of Wisconsin, he manages the Forest Landscape Ecology Lab, where work has been directed at sustainable forest issues in Wisconsin, such as old growth forest characteristics including structure, biodiversity, nutrient cycling, and carbon dynamics; developing and testing methods for reconstructing past forests and change; disturbance, ecological change, and management; and modeling of future forest landscapes under climate change and other scenarios. Mladenoff was the originator of the LANDIS forest model, which has been adapted and used in many locations in North America and elsewhere. He was also editor-in-chief of the journal *Landscape Ecology* from 1999-2005. Mladenoff earned his Ph.D. from the University of Wisconsin—Madison.

**Linda Joyce**'s research focuses on quantifying the effects of climate change on ecosystems, wildlife habitat, and the forest and wood products sector. As the Climate Change Specialist for the Forest Service Resource Planning Act national assessment, she works with resource specialists to include climate change in their analysis of forest and rangeland renewable resources over the 50-year planning horizon. She is also a co-principal investigator of the WestWide Climate Initiative—a partnership of Forest Service research and National Forests with the goal of developing a set of decision-support tools to incorporate climate-change considerations into resource management and planning. Joyce has contributed to the International Panel on Climate Change reports,

U.S. National Assessments on Climate Change, and the recent global assessment of forests by the International Union of Forest Research Organizations. She holds a B.S. in Mathematics from Grand Valley State College in Michigan; a Master of Environmental Science from Miami University in Ohio; and a Ph.D. in Range Ecology from Colorado State University.

**Richard Birdsey** is the project leader for the Climate, Fire, and Carbon Cycle Science group of the Forest Service's Northern Research Station. He is also responsible for coordinating a national research effort to analyze the impacts of international protocols on carbon accounting for the United States, and to identify forest management strategies to increase carbon sequestration. He spent 2 years as a Peace Corps forester in Ecuador, 10 years as a Research Forester with the Forest Service's Forest Inventory and Analysis Project at the Southern Research Station, and 3 years on the Forest Inventory and Analysis staff in the Washington Office of the

Forest Service. He has been Program Manager for Global Change Research for more than 10 years at the Northeastern and North Central Research Stations. Birdsey is a specialist in quantitative methods for large-scale forest inventories and has pioneered the development of methods to estimate national carbon budgets for forest lands from forest inventory data. Birdsey has a bachelor's degree in anthropology and a master's degree in world forestry. Birdsey received a Ph.D. in quantitative methods from the State University of New York, College of Environmental Science and Forestry.

**David Cleland** has more than 30 years with the Forest Service. He has worked in deputy positions in management and research at the National Forest, Research Work Unit, Regional Office, and Washington Office levels. He currently is the acting National Program Manager for Vegetation Ecology, Washington Office. He received his Ph.D. in Forest Ecology, Soils, and Quantitative Methods from Michigan State University.

## Appendix 4: Programs Mentioned in Report

Below is a list of programs that were mentioned in the breakout sessions with links to websites with more information.

### Monitoring Networks

- USA-National Phenology Monitoring Network: <http://www.usanpn.org/home>
- Forest Inventory and Analysis: <http://fia.fs.fed.us/>
- USGS National Water Information System (Stream Gauge Network): <http://waterdata.usgs.gov/nwis/rt>
- National Park Service Great Lakes Inventory and Monitoring Program: <http://science.nature.nps.gov/im/units/GLKN/>
- Ameriflux:
  - Chequamegon-Nicolet Ecosystem Atmosphere Study (ChEAS): <http://cheas.psu.edu/>
- National Ecological Observatory Network (NEON): <http://neoninc.org/>
- Eastern Forest Environmental Threat Assessment Center: <http://www.forestthreats.org/>

### Conservation Easements and Land Protection Programs

- Forest Legacy Program: <http://www.fs.fed.us/spf/coop/programs/loa/flp.shtml>
- Research Natural Areas: <http://www.nrs.fs.fed.us/rna/about/>
- Working forest conservation easements: <http://www.privatelandownernetwork.org/plnlo/working%20forest%20conservation%20easements.asp>
- Forest Stewardship Program: <http://www.fs.fed.us/spf/coop/programs/loa/fsp.shtml>

### Climate Change Tools and Models

- Climate Change Atlas: <http://www.nrs.fs.fed.us/atlas/>
- Forest Vegetation Simulator: <http://www.fs.fed.us/fmssc/fvs/>
- LANDIS-II: <http://www.LANDIS-II.org/>
- Template for Assessing Climate Change Impacts (TACCIMO): <http://www.taccimo.sgcp.ncsu.edu/>
- Wisconsin Initiative on Climate Change Impacts (WICCI): <http://www.wicci.wisc.edu/>



Brandt, Leslie; Swanston, Chris; Parker, Linda; Janowiak, Maria; Birdsey, Richard; Iverson, Louis; Mladenoff, David; Butler, Patricia. 2012. Climate change science applications and needs in forest ecosystem management: a workshop organized as part of the northern Wisconsin Climate Change Response Framework Project. Gen. Tech. Rep. NRS-GTR-95. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 53 p.

Climate change is leading to direct and indirect impacts on forest tree species and ecosystems in northern Wisconsin. Land managers will need to prepare for and respond to these impacts, so we designed a workshop to identify forest management approaches that can enhance the ability of ecosystems in northern Wisconsin to cope with climate change and address how National Forests and other lands could be used to test these approaches. The workshop had three major themes: (1) adaptation of forest management to current and expected climate change, (2) forest management to support greenhouse gas mitigation, and (3) monitoring of climate change impacts and the effectiveness of mitigation and adaptation strategies. A group of nearly 60 experts in the fields of forest science, policy, and forest resource management identified place-based management approaches and new research directions that addressed these major themes. One concept that emerged was the need to adapt not only ecological systems but social systems as well, and research to adapt social systems was identified as a key knowledge gap. Participants were cautious about the potential for northern Wisconsin lands to mitigate greenhouse gas emissions and enhance carbon sequestration through forest management. The experts identified the need for more research to quantify that potential, especially for non-forested lands and greenhouse gases other than carbon dioxide. Participants also agreed that mitigation strategies will not be effective in the long term unless they are carried out in conjunction with adaptation strategies. According to participants, current monitoring efforts in northern Wisconsin are insufficient to detect climate change impacts at spatial scales relevant to land management and are not as well-integrated with each other as they could be. However, participants identified several regional and national programs that could serve as models for integration. Outcomes from this workshop emphasized the importance of a place-based response to climate change. Forest managers in northern Wisconsin will need to establish and articulate clear goals for adaptation, mitigation, and monitoring, as well as ensure these goals are integrated with one another, in order to be effective at responding to climate change.

**KEY WORDS:** Chequamegon-Nicolet National Forest, climate change, adaptation, mitigation, monitoring, adaptive management, Wisconsin

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