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Responding to Challenges for Forested Watersheds in the Eastern Region

A synopsis of presentations and ideas from the

Water Resources Workshops in Region 9

Spring 2017 in *Minocqua, WI and Keene, NH*

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Responding to Challenges to Forested Watersheds in the Eastern Region

Background

Forests of the Midwest and Northeast define the character, culture, and economy of this large region, but face an uncertain future as climate continues to change. Forests vary widely across the region, and vulnerabilities are strongly influenced by differences in forest composition, disturbance regimes, and exposure to climate change. Northern forests provide substantial economic benefits to the region, with regional wood products and their manufacturing generating more than $175 billion annually (Shifley et al. 2012). These forests also provide 48 percent of the water supply in this region, serving large metropolitan areas such as New York City and Boston, as well as rural municipalities.

The ***US Forest Service*** and ***Great Lakes Restoration Initiative*** are supporting an effort to develop adaptation strategies for water resources to help regional land managers respond to the challenges of changing climate and land use. The ***USDA Northern Forests Climate Hub*** and the ***Northern Institute of Applied Climate Science (NIACS)*** have collaborated with land managers and researchers to develop a menu of water resources adaptation strategies for use with the Adaptation Workbook (Swanston et al. 2016).

NIACS worked with the ***Wisconsin Initiative on Climate Change Impacts***, ***Trout Unlimited***, and ***Antioch University New England*** to co-host two workshops in the spring of 2017, providing information about water resource challenges and developing adaptation actions for real-world projects. Federal and state agencies, universities, tribes, and conservation organizations presented state-of-science information on observed and projected changes in forest and water resources across the region. Workshop participants—including foresters, hydrologists, aquatic biologists, and water quality specialists—described climate change vulnerabilities on the lands and waters that they manage. Participants then tested the draft water resources menu using on-the-ground projects, identifying adaptation actions designed to meet resource management objectives.

(Forest Service photo)

Low stream flow on Hubbard Brook, NH

Types of drought include:

- ***Meteorological*** **– degree of dryness in weather over a defined period of time;**
- ***Agricultural*** **– links meteorological drought with agricultural impacts;**
- ***Hydrological*** **– precipitation deficits, with emphasis on effects on the hydrological system (e.g., water storage and flux); and**
- ***Socio-economic*** **– demand for economic goods exceeds supply as a result of weather/climate-related shortfall in water supply (Wilhite and Glantz 1985).**

In terms of forested and rangeland ecosystems, *ecological drought* is an episodic deficiency in water availability that drives ecosystems beyond thresholds of vulnerability, affects ecosystem services, and triggers feedbacks in natural and human systems (Crausbay et al. 2017).

Humans also contribute to or alleviate drought by modifying hydrological processes (e.g., through land use, irrigation, and dam building) (Van Loon et al. 2016).

Forested Watersheds in the Eastern Region

The Eastern Region contains diverse ecosystems and tree species. Anticipated climate change effects, such as increased temperatures, extended growing season, variable precipitation, reduced snowpack and earlier melt, and episodic precipitation events, can interact to increase drought risk and stress forest ecosystems (Handler et al. 2014). Droughts may alter these ecosystems, affecting forest vigor and productivity, carbon storage, and water yield and quality (Vose et al. 2016).

The Eastern Region is expected to continue receiving increased annual precipitation (Melillo et al. 2014), and most of the region has experienced a slight decrease in drought frequency during the 20th century (Vose et al. 2016). Seasonal and spatial distribution, intensity, and type of precipitation are also changing (Peters et al. 2014, Vose et al. 2016) (Figure 1).

Although a variety of climate models indicate that annual precipitation may remain stable or increase slightly, projections of precipitation during the growing season have greater variability and some models project reduced summer precipitation in the future (Lynch et al. 2016, Ning et al. 2015). It is also likely that near-term extreme rainfall events will continue, potentially resulting in longer dry periods between events (Melillo et al. 2014, Ning et al. 2015). In addition, rising temperatures may cause drier conditions during the growing season, because warmer temperatures create greater evaporative demand.

Higher precipitation during some seasons, coupled with greater evaporative demand from warmer temperatures, mean that forested watersheds may be affected by both wetter and drier conditions at different times of the year (Figures 2 and 3). Warmer, shorter winters may reduce snow cover and increase early season streamflows (Huntington et al. 2009) (Figure 4). More cold season precipitation events are expected to occur in the form of rain and rain-on-snow, resulting in more runoff and less water storage during the growing season (Campbell et al. 2011, Handler et al. 2014). Warmer temperatures during the growing season may reduce streamflows, desiccate plants, and reduce soil moisture where precipitation does not compensate for increased evaporative demand.

Drought may occur later in the summer and in early autumn due to limited moisture availability, increasing stress on trees and reducing forest growth (Handler et al. 2014). Extreme precipitation events increase the potential for erosion, sedimentation, flooding, and infrastructure damage.

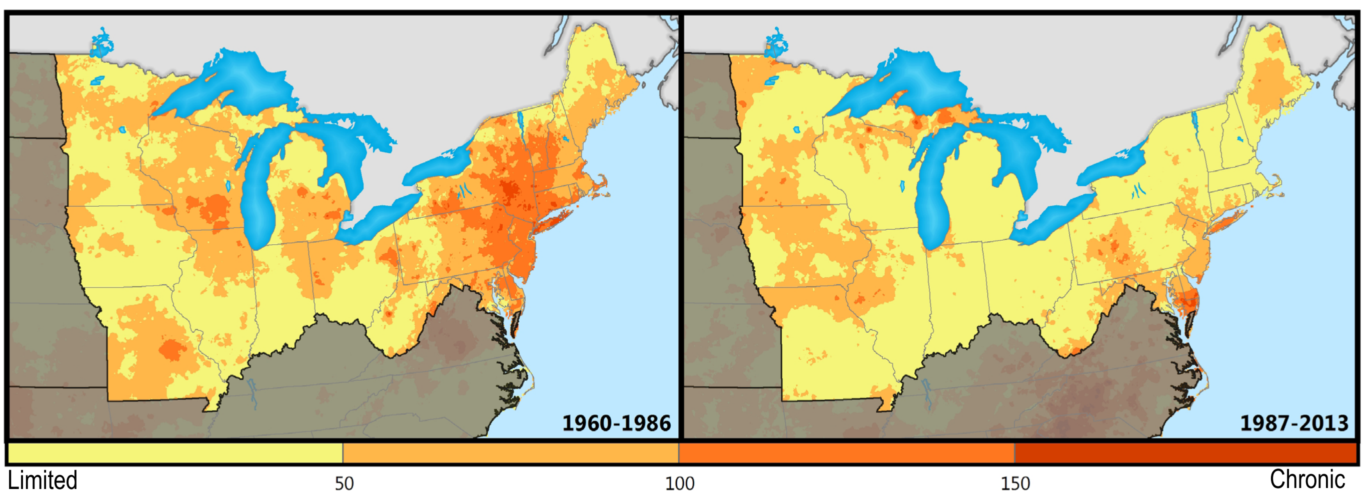

Figure 1 - Cumulative drought severity index, calculated using weighted monthly frequencies of Palmer Drought Severity Index values, reported for the periods 1960–1986 and 1987–2013. This indicates the duration and intensity of the long term drought effects based on historical precipitation and temperature. [Click on map for an interactive version.](#) See also: [Spatio-temporal trends of drought by forest type in the conterminous United States, 1960-2013.](#)

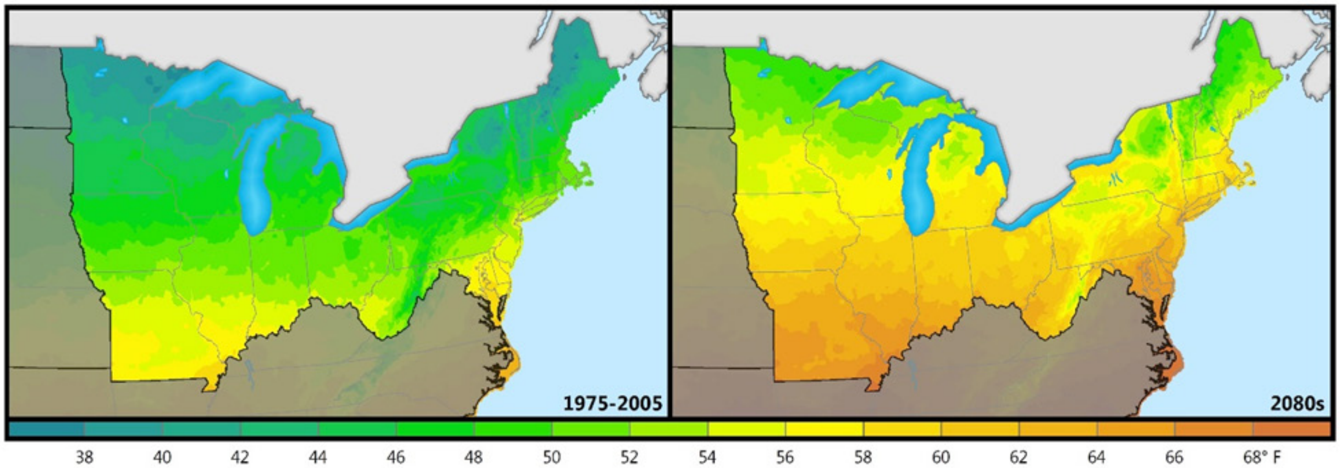

Figure 2 - Annual average temperature, modeled for 1975-2005 and the 2080s, using a high greenhouse gas emission scenario (RCP8.5; no climate policy and high population). Click on map for interactive version. For more climate maps, visit the Rocky Mountain Research Station's Air, Water, and Aquatic Ecosystems website.

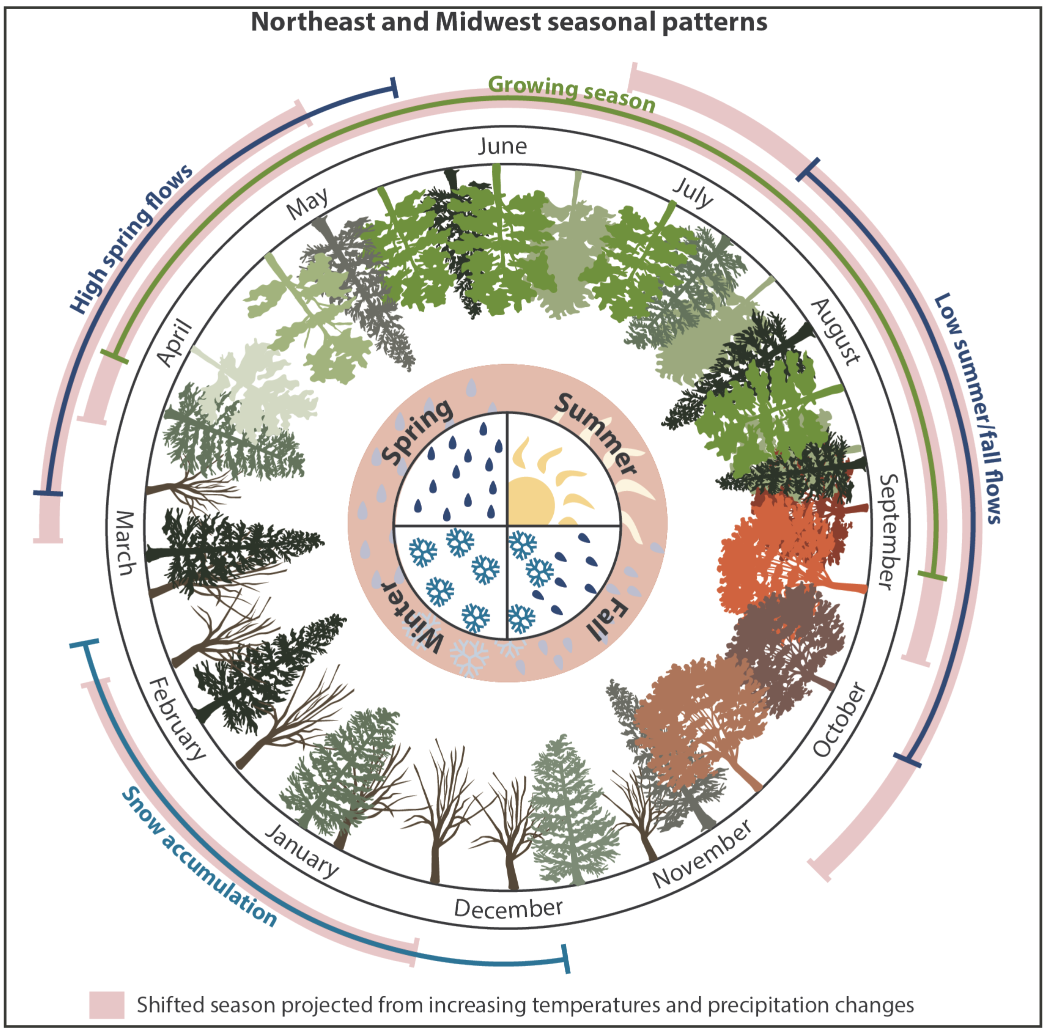

Figure 3 - Anticipated changes in seasonal patterns in the Midwest and Northeast, including changes in snow cover and stream flows. Figure courtesy of the Northeast Climate Science Center (Costanzo et al. 2016).

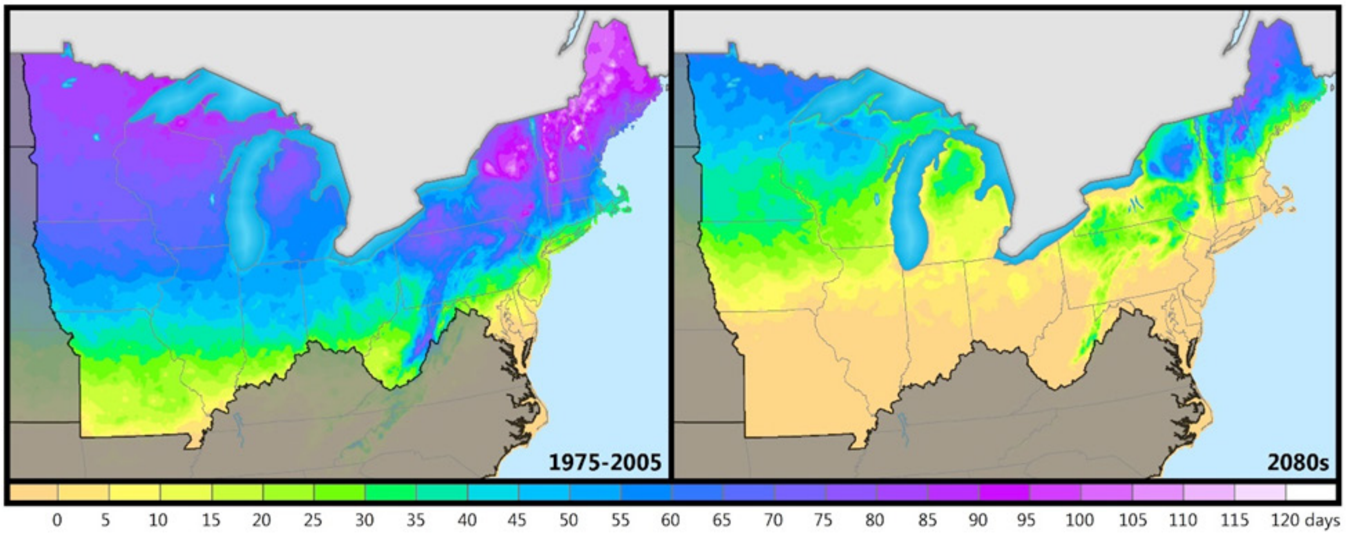

Figure 4 - Snow residence time, modeled for 1975-2005 and the 2080s, using a high greenhouse gas emission scenario (RCP8.5; no climate policy and high population). Click on map for an interactive version. For more climate maps, visit the Rocky Mountain Research Station's Air, Water, and Aquatic Ecosystems website.

Effects of a Changing Climate in the Eastern Region

» ***Increased temperatures and altered precipitation may increase moisture stress.*** Warmer temperatures will increase water temperatures and drive water losses from plants and forest soils, requiring more precipitation to maintain the water balance (Vose et al. 2016). Reduced winter snow, earlier spring flows, and a greater concentration of precipitation falling during extreme precipitation events may increase moisture stress during the growing season.

» ***Extreme precipitation events alter hydrologic cycles.*** Increases in the frequency and intensity of extreme precipitation events are expected to increase potential damage to forests and waterways from erosion, sedimentation, and flooding. The risk of damage to culverts, bridges, and other infrastructure is also expected to increase.

» ***Drier conditions may favor drought-tolerant species.*** Species that are able to tolerate hotter and drier conditions may be better adapted to drought-prone sites, making those species more competitive.

» ***Habitats may shift, favoring species more tolerant of hotter and drier conditions.*** Habitat for many northern tree species is expected to decrease, presenting opportunities for tree species currently located farther south to become established (Iverson et al. 2017). Species tolerant of hotter and drier conditions, including some oak, pine, and hickory species, may have increased habitat in the future.

» ***Low-diversity forest systems are at higher risk.*** Diverse ecosystems are generally more resilient to disturbance because they have more options to respond to change.

» ***Invasive plant species and insects will increase or become more damaging.*** Warmer temperatures may help invasive plant species and insects expand into new areas (Sturrock et al. 2012, Weed et al. 2013). Drought and other stressors can create opportunities for invasive plants and insects to cause damage.

» ***Climate conditions may increase the risk of wildfire by the end of the century.*** The fire season may shift or lengthen (Kerr et al. 2016). Risk is likely to be greater in forests that are under stress from other climate impacts or have higher fuel loads from insect-caused mortality, blowdown, or other disturbances.

» ***Aquatic organisms could face increased stress from heat and reduced water quality.*** Reduced streamflow can concentrate nutrients and sediments, warming waters more quickly (Poff et al. 2002). Some types of organisms, such as coldwater fish species, may be at greater risk.

» ***Some forests will be more vulnerable than others.*** Responses of individual forests and watersheds will vary, based on degree of warming, altered precipitation patterns, site conditions, and sensitivity of individual trees (Swanston et al. in press, Vose et al. 2017).

Forest Vegetation

Many options and resources are available to help resource managers meet management goals and local needs (Swanston et al. 2016). In many cases, "win-win" actions can promote the overall health of forests and increase their ability to adapt to altered future conditions. A complete list of adaptation strategies and approaches for forest management is available in the Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers (Swanston et al. 2016).

Forest Vegetation Management Responses

» ***Increase forest diversity*** by promoting a variety of species, including those that are tolerant of warmer and drier conditions, in order to reduce risk from climate change and help reduce forest vulnerability to drought. When planting, managers may consider species and genotypes that may be better adapted to current and future conditions. Species that have a broad range of ecological tolerances may grow better in a variety of future conditions.

» ***Increase drought- and heat-tolerant species and genotypes*** in areas that may be most vulnerable to drought. Managers may want to favor or plant species or genotypes that are tolerant of hotter and drier conditions on narrow ridge tops, south-facing slopes with shallow soils, or other sites that are expected to become warmer and drier.

» ***Manage stand density and structure*** to give trees adequate resources to grow. Managing tree age, size, and structure within forest stands can improve resistance and resilience to drought (Clark et al. 2016, D'Amato et al. 2011) and to insects and diseases. Management systems that promote a diversity of age classes and tree sizes can decrease risk across large landscapes, reducing the effects of disturbances (O'Hara & Ramage 2013).

» ***Control competition, including invasive species.*** Management to favor and tend desired species will become even more important as other stressors increase.

» ***Retain harvest residues*** to increase moisture availability, resulting in a mulching effect (Vose et al. 2016).

Water Resources

Clean water is a critical resource for natural ecosystems and people (Figure 5). Actions to protect and enhance water quality can take place across a watershed, including both management of upland vegetation (described above) and direct actions focused on water resources. A complete list of adaptation strategies and approaches for forest management is available in the Forest Adaptation Resources.

Water Resource Management Responses

» ***Protect and restore forests and vegetative cover*** to maintain diverse, resilient forest in uplands, wetlands, and riparian areas. This includes reducing invasive species, revegetating areas after disturbances, and protecting sensitive and unique habitats. Managers can consider facilitating forest community adjustments to cope with drought or periods of inundation based on management goals and local conditions.

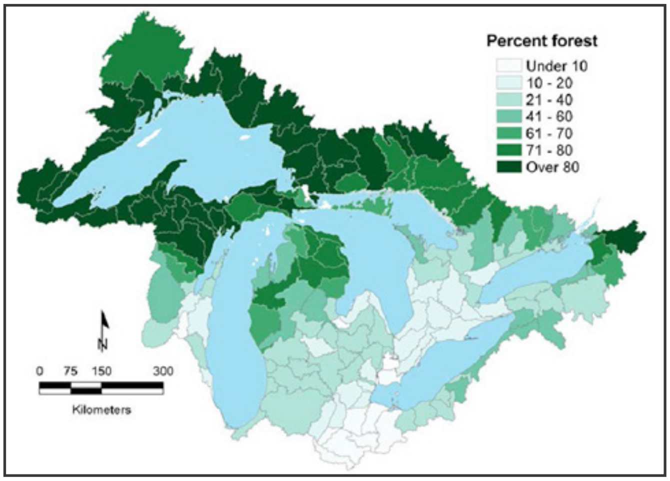

Figure 5 - Percent forest cover in watersheds across the Great Lakes basin, including forest wetlands (Environment Canada and UP EPA, 2014, [State of the Great Lakes 2011]).

» ***Protect water quality*** by promoting healthy forests and vegetation. Management actions already in place to protect water quality will be more important in a changing climate. Maintaining riparian areas and stream shading can moderate stream temperature increases. Best management practices can reduce soil erosion and sedimentation.

» ***Maintain and enhance hydrologic processes*** across the landscape by minimizing erosion and sedimentation, and encouraging water infiltration and storage. Restoring hydrologic connectivity to floodplains, wetlands, and streams can create additional water storage on the landscape, and restoring wetlands can improve their ability to capture, store, and slowly release water.

» ***Accommodate altered hydrologic processes*** to changing conditions. For example, degraded stream channels can be modified to increase resilience to extreme events and improve aquatic habitat.

» ***Design and modify infrastructure to match future conditions*** by making it stronger and more robust. It may be preferable to redesign or remove infrastructure to minimize its impact on the landscape or to incorporate natural or low impact development into designs.

Adaptation Examples in the Eastern Region

More than 200 adaptation demonstration projects in the Eastern Region provide on-the-ground examples of climate-informed land management activities across diverse locations, ownerships, ecosystems, and resources. All projects have used the Adaptation Workbook process outlined in Forest Adaptation Resources to identify actions that will meet management goals and adapt to changing conditions. The three adaptation demonstrations presented here provide examples of the types of projects for which a new menu of water resources adaptation strategies will be useful.

Providence Water: Adapting Forests to Drought

Providence Water, a publically owned water utility providing water to two-thirds of Rhode Island residents, is managing forests to be better adapted to future drought conditions. In keeping with goals to maintain and protect water yield and water quality, the utility is managing for a diversity of species, including those tolerant of extended drought, by planting tree species from southerly seed zones in the project area.

The Scituate Reservoir and five smaller tributary reservoirs are the primary drinking water source for approximately 600,000 people. The reservoirs are surrounded by 13,000 acres of mostly forested public land (formerly agricultural lands). These reservoirs serve as “green infrastructure” by filtering surface runoff and act as the first step in the water treatment process.

The woodlands surrounding the reservoir are currently experiencing hardwood regeneration failure caused by insects, pathogens (e.g., red pine scale, red pine adelgid, gypsy moth, orange-striped oakworm, chestnut blight), and deer herbivory. Anticipated shifts in climate may interact to increase severe weather and drought risks, further challenging regeneration of local species. Warming and altered precipitation patterns may result in less winter snow, and drier conditions persisting later in the growing season. Prolonged drought may reduce the vigor of forest species unable to tolerate hotter and drier conditions. A changing climate is likely to intensify many interacting forest stressors including insects, invasive plant species, and deer herbivory.

Figure 6 - Dry conditions, deer herbivory, and insect pests have contributed to regeneration failure at this site (photo courtesy of Christopher Riely, Providence Water).

Through Providence Water's [Planting Future-Adapted Forests] project, the utility is experimenting with actions that promote ecosystem "transition" to a diverse forest that is better adapted to future conditions. Providence Water has identified management actions to prepare forests for a changing climate, including:

» In oak forest with regeneration failure, guide changes in species composition by planting species better adapted to future conditions (e.g., black oak, black locust, white oak, pin oak, persimmon, sweetgum, eastern red cedar, sassafras, loblolly pine, pitch pine, and shortleaf pine), and tending tree seedlings as needed.

» Plant future-adapted tree seedlings in areas where herbivory can be minimized and protect these seedlings, including deer exclosures where necessary.

» In upland oak stands with harvest decline and poor quality trees, conduct enrichment planting with future-adapted tree seedlings (e.g., black locust, black oak, chestnut oak, persimmon, shortleaf pine, sweetgum, Virginia pine, and white oak).

Providence Water will monitor the success of these tactics—going beyond current forest inventory data—to assess deer browse impacts and the growth and survival of the future-adapted seedlings. Two sites on Providence Water land have been planted with future-adapted species, and additional planting is being considered.

Florence County: Restoring a Forest Following Drought

Florence County Forestry and Parks manages more than 36,000 acres of forestland in northeastern Wisconsin for timber production and public uses such as hunting, fishing, and camping. The county is restoring 400 acres of forestlands that were significantly affected by drought and insects, with a goal to be better adapted to future drought conditions.

Florence County contains large forests on sandy, nutrient poor sites. The declining precipitation in northern Wisconsin over the past several decades has stressed forests, leading to mortality in some areas. The stands selected for this project had experienced close to 90 percent mortality caused by drought and forest insects (e.g., two-lined chestnut borer). This site may continue to be susceptible to drought and other stressors, including excessively well-drained soils, warmer temperatures, earlier snowmelt, and drier growing seasons.

Florence County is motivated to keep this area forested, and worked with partners to devise adaptation tactics to help the forest tolerate drought. As part of their [Climate-Informed Forest Restoration] project, Florence County harvested most of the dead and dying trees, reserving healthy pockets of scrub oak and northern red oak. They planted native species expected to be better adapted to dry conditions (jack pine, red pine, and white pine in the uplands; white pine and swamp white oak in wetter areas). The county added wood-based soil amendments (wood ash and biochar) to 100 acres of the project area to improve soil water holding capacity, nutrient exchange, and microbiota.

This project is the first large scale field trial of soil amendments in Midwest forests. Monitoring is underway to measure the survival and growth of seedlings, as well as soil factors such as water holding capacity, bulk density, pH, and cation exchange (Richard et al. 2017).

Figure 7 - A red pine seedling planted with a biochar soil amendment (Forest Service photo).

Chequamegon-Nicolet National Forest: Preparing for Extreme Rainfall

Chequamegon-Nicolet National Forest resource managers have been working for several years to identify infrastructure upgrades necessary to improve watershed conditions. Narrow or undersized culverts build up a high head at moderate flood flows, creating a scour pool downstream and greater pressure and turbulence on the structure. Such culverts are often set too high, causing high velocity through the pipe and restricting movement of aquatic organisms. When these culverts fail, large amounts of water, sand, and gravel are transported downstream, causing substantial erosion and sedimentation.

In the Marengo and Twentymile Creek Watersheds project, the national forest has designed new culverts and road-stream crossings to withstand larger rainfall events. This work was tested in July 2016 when a major rainstorm dropped 10 inches of rain in some locations in northern Wisconsin and caused a state of emergency in eight counties. The improved infrastructure held up quite well, with 17 of the 20 recently installed culverts surviving the storm despite being overtopped by floodwaters. In this case, proactive implementation of climate-resilient infrastructure clearly benefited both riparian ecosystems and human values.

The infrastructure project was the culmination of many years of data gathering and modeling, followed by prioritization of locations considered to be especially vulnerable (Furniss et al. 2013). The Chequamegon-Nicolet National Forest has been implementing and refining “stream simulation” design for several years (US Forest Service 2008), with the intent of providing passage of aquatic organisms upstream and downstream at stream crossings, allowing water, wood, and sediment to move downstream at their natural rate. Sizing culverts to the bankfull width of the channel is a key component of stream simulation. Typically, culverts sized to bankfull width or greater will pass a 100-year flood with the water surface below the top of the culvert. The design is modified as necessary to ensure the water level for such a flood is no more than 80 percent of the height of the culvert. With increased flood capacity and a natural streambed inside the culvert, the lifespan of culverts is extended significantly.

Figure 8 - Road damage after a 10-inch rainstorm in northern Wisconsin in July 2016 (Forest Service photo)

The Chequamegon-Nicolet National Forest expects that strategic infrastructure upgrades will save money over the long term because the improvements typically have a longer lifespan and reduced maintenance costs. In addition to cost savings, the stream crossings that did not fail during the July 2016 flood allowed roads to remain open as evacuation routes, ensuring the safety of rural residents.

Summary

Forests and associated natural ecosystems provide vital environmental, economic, social, and cultural benefits to the Eastern Region. Climate change will exert different pressures for ecosystem change in these forests, presenting the people who rely on forests with a variety of challenges.

Effective responses to rapid changes in the timing, intensity, and distribution of otherwise familiar stressors and ecosystem drivers can be most efficiently addressed by a community of land managers with diverse experience and resources. Land managers and land owners are already devising responses to these challenges, and continued communication and shared learning within this community will ensure that heathy and productive forests can be sustained in the future.

Forest Service photo

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