

EXECUTIVE SUMMARY



Forests of the
Northern
United States

Manuscript received for publication: August 2011

Published by:

USDA Forest Service

Northern Research Station

11 Campus Blvd, Suite 200

Newtown Square, PA 19073

March 2012

For additional copies:

U.S. Forest Service

Publications Distribution

359 Main Road

Delaware, OH 43015

Fax: 740-368-0152

Visit our homepage at: <http://www.nrs.fs.fed.us>



Forests of the Northern United States

EXECUTIVE SUMMARY

This executive summary provides an overview of the 200-page report, *Forests of the Northern United States*¹, which covers in detail current forest conditions, recent trends, issues, threats and opportunities in the forests in the 20 Northern States. It provides a context for subsequent Northern Forest Futures Project analyses that will forecast alternative future scenarios and their potential impacts on forests and people in the North. Facts and figures cited in this executive summary come from numerous publications and online databases; specific sources and many additional details are included in the full report.

¹ Shifley, Stephen R.; Aguilar, Francisco X.; Song, Nianfu; Stewart, Susan I.; Nowak, David J.; Gormanson, Dale D.; Moser, W. Keith; Wormstead, Sherri; Greenfield, Eric J. 2012. *Forests of the Northern United States*. Gen. Tech. Rep. NRS-90. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 202 p.

also available at
<http://www.nrs.fs.fed.us/futures/>



NORTHERN FORESTS AND PEOPLE

The Northern United States is comprised of the 20 States bounded by Maine, Maryland, Missouri, and Minnesota. It is the most heavily forested and populated quadrant of the United States (Fig. 1). In the last century the population in the North increased from 52 to 124 million people (138 percent). Over that same period forest land in the region increased from 134 to 172 million acres (28 percent)

while total U.S. forest land remained essentially unchanged (Fig. 2). In the last 50 years the volume of standing timber increased from 104 to 248 billion cubic feet (138 percent). These trends are attributable to historical patterns of forest harvesting, land clearing, farming, farm abandonment, natural regeneration, and urbanization that continue to influence the region's forests today.

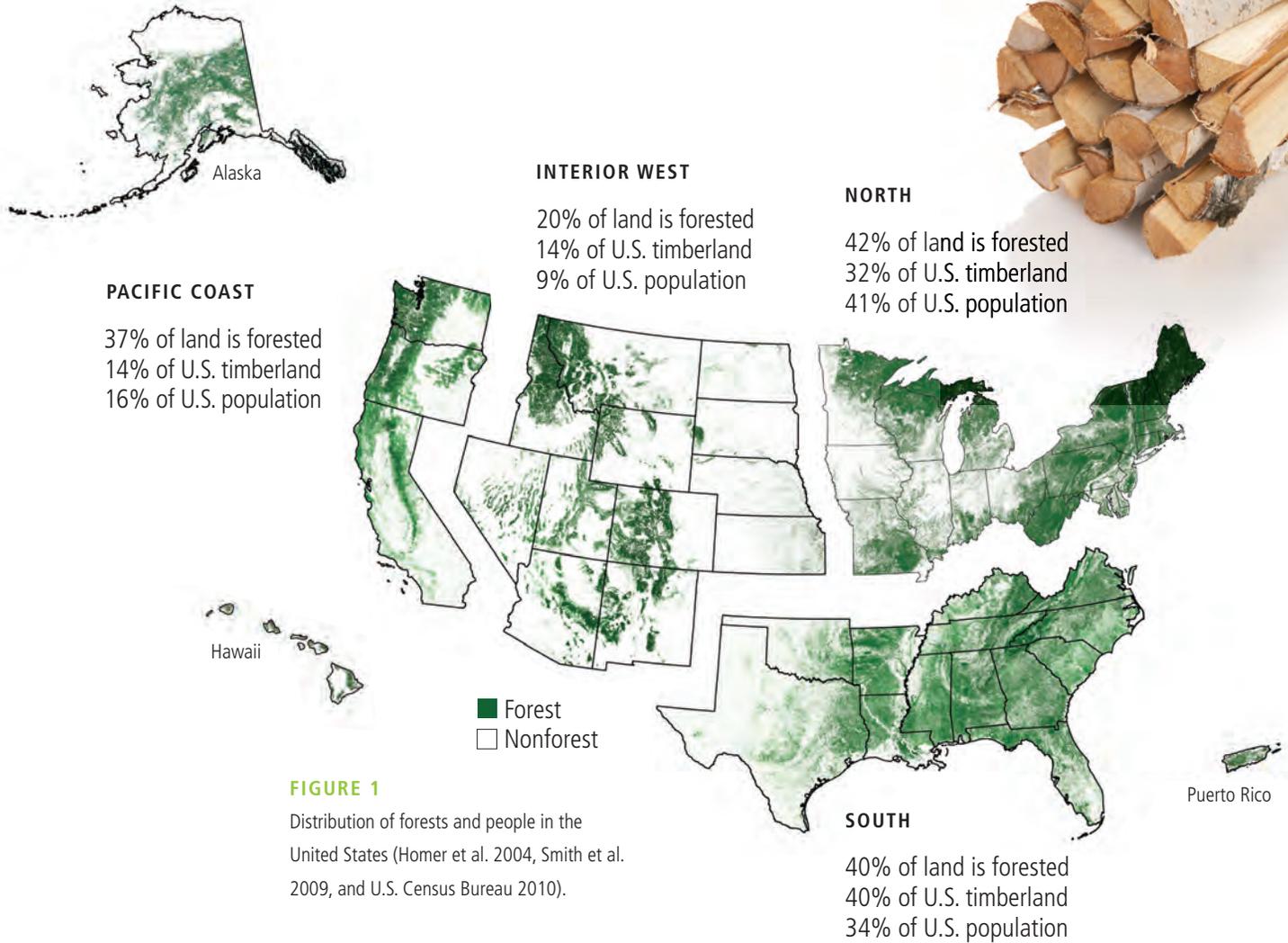


FIGURE 1
Distribution of forests and people in the United States (Homer et al. 2004, Smith et al. 2009, and U.S. Census Bureau 2010).

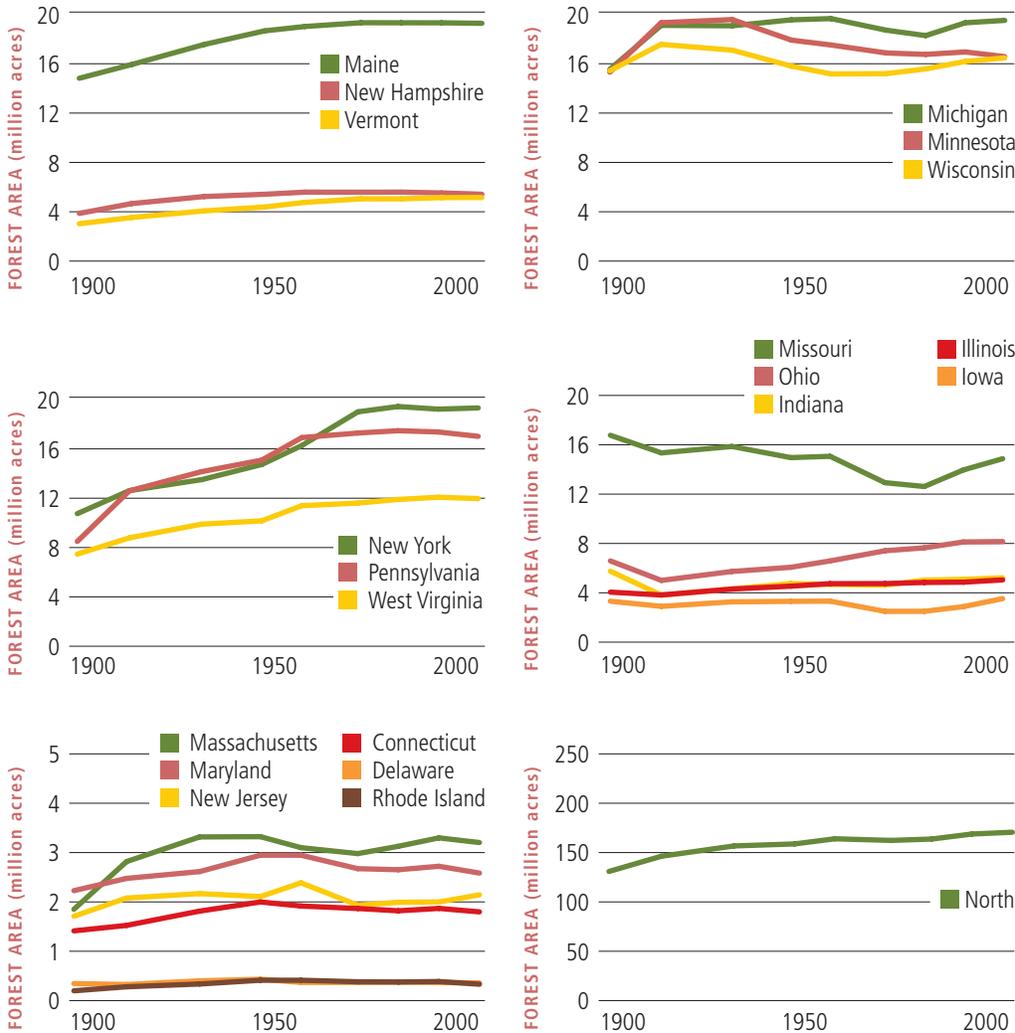


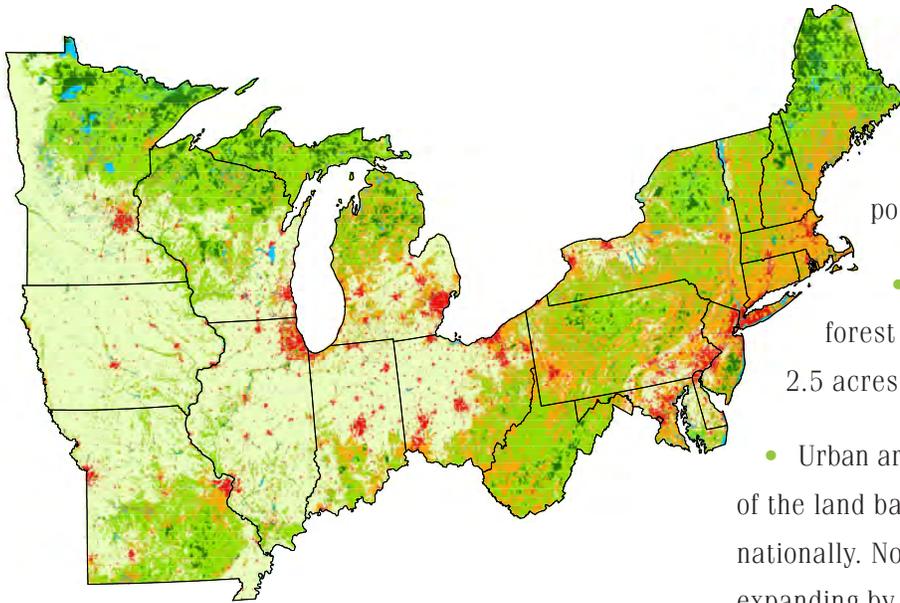
FIGURE 2
Forest area by State
from 1907 to 2007
(Smith et al. 2009).

People depend on the North's forests for renewable natural resources such as wood and wildlife; for employment and economic development; for vital ecosystem services such as the provision of clean air, clean water, climate regulation, and biodiversity; and for recreation.



The information in this assessment helps put the capabilities and limitations of northern forests in perspective with the rest of the Nation. For example:

- With only 18 percent of total land area, the North includes 32 percent of the Nation's timberland (public or private forest land that is sufficiently productive and sufficiently accessible to produce commercial crops of wood and that is not otherwise restricted from timber harvest by policy or legislation).



- The North hosts 41 percent of the Nation’s population, and 80 percent of the North’s population lives in urban areas.

- The North has 1.4 acres of forest land per capita compared to 2.5 acres nationally.

- Urban areas in the North cover 6 percent of the land base compared to 3 percent nationally. Northern urban areas are expanding by about 4 million acres per decade, and 37 percent of that expansion (1.5 million acres) is into forest cover.

WILDLAND-URBAN INTERFACE (WUI)

WUI

■ Intermix and interface

NON-WUI VEGETATED

■ Very low density housing

■ No housing

NONVEGETATED OR AGRICULTURE

■ High and medium density housing

■ Low and very low density housing

■ Water

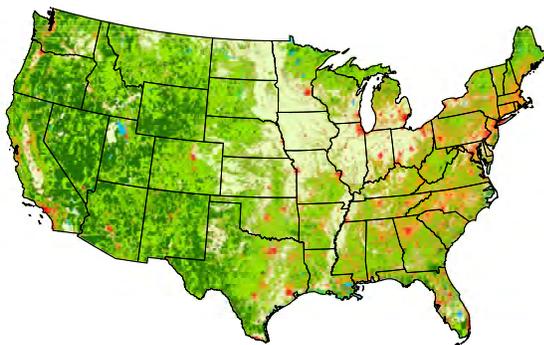


FIGURE 3

The wildland-urban interface (Radeloff et. al 2005). The majority of the area of wildland-urban interface and intermix occurs in the eastern United States.

- The North has large areas of wildland-urban interface compared to the rest of the United States (Fig. 3).

- Current statewide tree mortality rates are 1 to 2 percent of total volume per year, but native and invasive insects and diseases can cause severe, localized damage or mortality.

- Introduction of new invasive species is an ongoing threat to forest health in the North and in the rest of the United States.

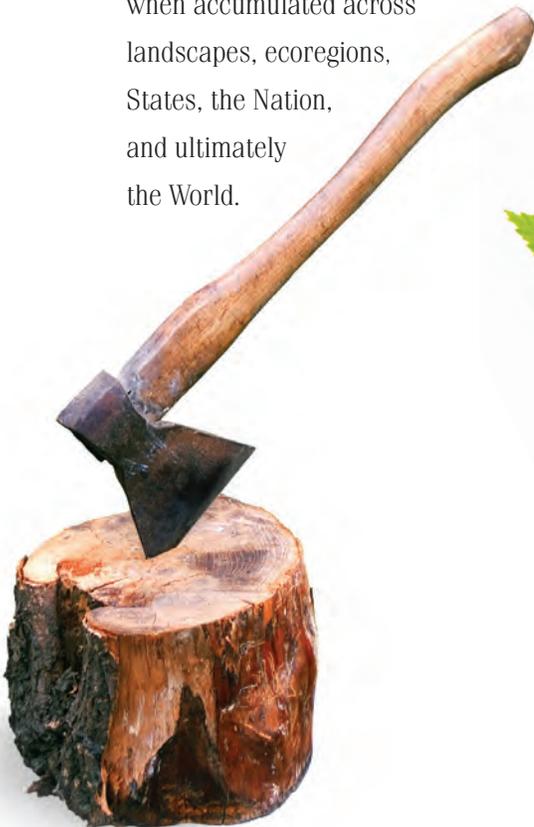
- Across the North, 48 percent of the water supply originates on forest lands, compared to 53 percent nationally.

- In the North, one acre of forest land in six (16%) is afforded some form of protected status.

- Annual volume growth of northern forests was about 6.6 billion cubic feet for State inventory cycles completed through 2008. Annual volume growth is 1.9 times greater than the rate of harvesting and other removals, compared to 1.7 times nationally.
- People in the North consume the equivalent of 8.8 billion cubic feet of wood each year or about 71 cubic feet per person, most of which is harvested and processed elsewhere.
- The region currently employs 441,000 in the forestry, logging, wood products, and pulp and paper industries—about 40 percent of all U.S. jobs for these sectors.

Understanding northern forests requires the ability to see forests at multiple spatial scales. The combined effects of millions of individual decisions about forest management or product consumption may have unforeseen impacts when accumulated across landscapes, ecoregions, States, the Nation, and ultimately the World.

This is especially true when considering the wide array of products, amenities, and ecosystem services that forests provide and the inherent tradeoffs associated with alternative management objectives. Consequently, it is essential to examine forest conditions in a hierarchical, spatial context across landscapes and large ecological regions. Likewise, because many forest policies are established by legislative bodies, it is informative to examine forest conditions at several political scales: States, multi-State regions, and the Nation. Scale issues are important in both directions. We commonly scale up or aggregate to understand the cumulative effects of management practices, but implementation of forest policies established nationally or by individual States often requires scaling down to resolve the forest management logistics acre-by-acre on the ground.



CONTEMPORARY ISSUES FACING NORTHERN FORESTS

Despite some notably positive forest-area and timber-volume trends within the North, numerous and widespread issues or concerns associated with northern forests have been compiled from multiple sources published from 2004 to 2009 (Dietzman et al. 2011).

These include:

- Minimizing losses to insects and diseases
- Excluding or controlling invasive species
- Implementing appropriate management standards and practices
- Maintaining existing forest area while providing desired combinations of species composition and forest size/age structure over time
- Increasing the forest area covered by stewardship plans
- Sustaining viable wildlife populations and overall forest biodiversity
- Reducing rates of forest fragmentation and parcelization
- Sustaining or increasing the quantity and quality of water from forest lands.
- Sustaining wood products, pulp, and paper industries

- Increasing environmental literacy
- Increasing participation in nature-based recreation
- Increasing use of woody biomass for energy while considering demand for other wood products

State Forest Action Plans recently prepared by the 20 northern States (USDA FS and NAASF 2011) identified four additional issues of widespread concern:

- Creating healthy, sustainable urban and community forests
- Managing forests in a changing climate
- Controlling wildfire threats to forests, public safety, and property
- Increasing capacity for forest management on State and private forests



SUSTAINABLE NORTHERN FORESTS

A goal of the Northern Forest Futures Project is to better understand how future changes to northern forests will affect sustainable development. The Brundtland report on sustainable development (World Commission on Environment and Development 1987) suggested sustainable development needs to account for (1) meeting current and future human needs; (2) limitations in meeting those needs based on technological capabilities, social organization, and environmental resources; and (3) the ability of the biosphere to absorb the effects of human activities.

Although there is widespread endorsement of the principles behind sustainable development, associated guidelines for sustainable forest management are still evolving for northern forests and elsewhere. Quantifying intermediate and long-term objectives for sustainable development of forests is complicated by the diversity of values among people who depend on forests, the diversity of forest conditions, and the diversity of spatial and temporal scales that must be considered. This complexity leads to challenges in setting objectives and in implementing associated monitoring systems. The following are important general strategies for sustainable development of forests in the North, because they can help assure we meet current and future needs while maintaining functional forest ecosystems:

- Maintain a stable forest land base
- Maintain or enhance forest biodiversity
- Maintain or enhance soil productivity and minimize soil erosion and contamination
- Maintain or enhance desired levels of water yield and water quality from forests
- Maintain diverse forest size/age structure and species composition
- Maintain or enhance levels and flows of a full complement of forest benefits including timber and nontimber products, recreation experiences, viable plant and animal populations, clean water, clean air, and carbon sequestration
- Maintain or enhance the capacity for sustained yield of forest products
- Maintain or enhance forest-based employment and community stability
- Maintain or enhance a system of institutions, policies, regulations, and incentives that support sustainable forests
- Maintain or enhance forest resilience through healthy, diverse forests that can absorb inevitable disturbances and still continue to function as forests

Many readers will note that the above strategies cannot all be pursued equally, and pursuing some will sacrifice the extent to which others can be pursued. Tradeoffs and compromises are inevitable in striving for sustainable forests. Sustainable forest management requires careful thought about the full range of benefits and consequences associated with alternative management actions or inaction.



Ash Cave, Hocking Hills Region, Ohio

NORTHERN FOREST CONDITIONS: AN OVERVIEW OF EIGHT FOREST DIMENSIONS

The next sections highlight conditions for eight different aspects of northern forests. The first seven sections follow the outline of the Montréal Process Criteria and Indicators (Montréal Process Working Group 2010), and the eighth is focused on urban and community forests which occur in close proximity to places where most northern residents live. The Montréal Process Criteria and Indicators are a widely used framework for organizing information about forest conditions at local, State, regional, national, and global spatial scales. The names of the eight criteria examined are:

1. Conservation of biological diversity
2. Maintenance of productive capacity of forest ecosystems
3. Maintenance of forest ecosystem health and vitality
4. Conservation and maintenance of soil and water resources
5. Maintenance of forest contributions to global carbon cycles
6. Maintenance and enhancement of long-term multiple socioeconomic benefits to meet the needs of societies
7. Legal, institutional and economic framework for forest conservation and sustainable management
8. Urban and community forests

The following pages provide summary information for each of these criteria, and Table 1 (beginning on page 32) provides summary information for specific indicators that are addressed in detail in the full report.



Key Findings for Criterion 1:

CONSERVATION OF BIOLOGICAL DIVERSITY

- Forests cover 172 million acres in the Northern States or 42 percent of the land area.
- Forest area in the region increased by 28 percent over the last 100 years.
- The region's forest land is 74 percent privately owned.
- There are 5 million private forest owners.
- Oak-hickory and maple-beech-birch are the most common forest types; together they account for 64 percent of the forest area.
- Young forests and old forests are relatively rare; 70 percent of the forest area is between 40 and 100 years old.

- About 1 percent of the region's forest-associated species are presumed extinct; populations of 85 percent of forest-associated species appear to be secure. Populations of the remaining forest-associated species are at some degree of risk.
- The number of extirpated forest-associated species is greater in the Northern States than elsewhere in the United States (Fig. 4) (Table 1, see page 32).

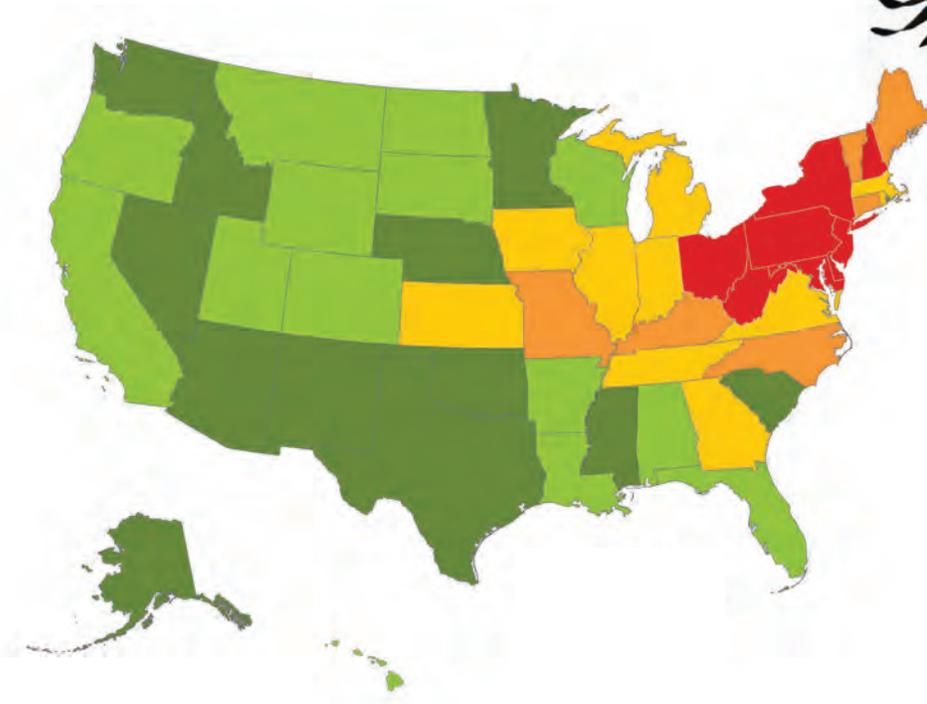


FIGURE 4

The number of forest-associated species—vascular plants, vertebrates (excluding freshwater fish), and select invertebrates—that have been extirpated within each State; map by Curtis Flather (USDA FS 2011b, NatureServe 2010).

NUMBER OF SPECIES EXTIRPATED

■ Under 25	■ 76 to 100
■ 25 to 50	■ Over 100
■ 51 to 75	



Key Findings for Criterion 2:

MAINTENANCE OF PRODUCTIVE CAPACITY OF FOREST ECOSYSTEMS

- Of the North's 172 million acres of forest land, 164 million acres (95 percent) are classified as timberland and capable of timber production.
- The region's timberland is 77 percent privately owned (Fig. 5), but private ownership ranges from 46 percent in Minnesota to 96 percent in Maine.
- Regional wood growth has exceeded removals for at least five decades.
- Since 1953, standing volume has increased substantially in all 20 States.

- Only 3.5 percent (6 million acres) of northern forests are plantations.
- Pennsylvania, Michigan, New York, West Virginia, and Maine have the greatest total volume of timber among States in the North, more than 20 billion cubic feet each (Fig. 6).
- Massachusetts, Maryland, New Hampshire, Vermont, Connecticut, and West Virginia, have the highest average volume per acre of timberland—more than 1,900 cubic feet per acre, each (Table 1).

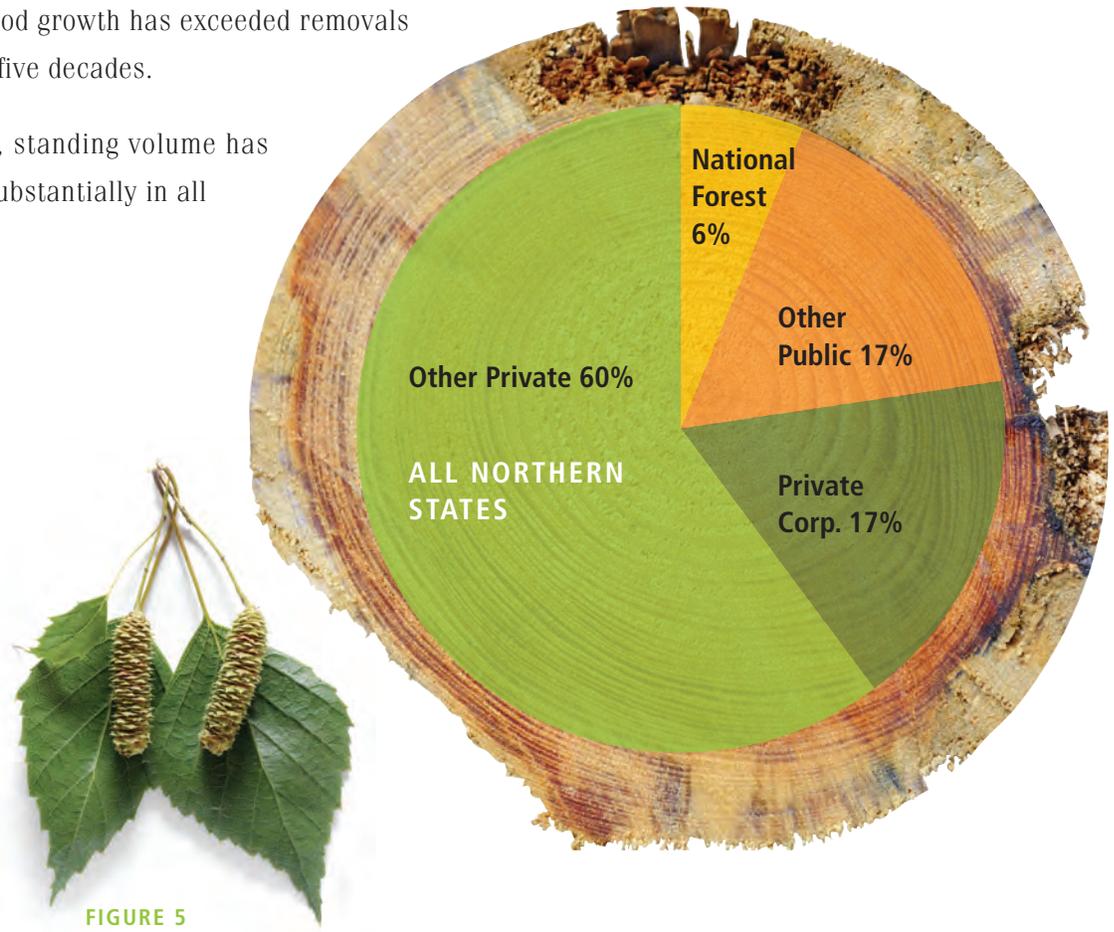


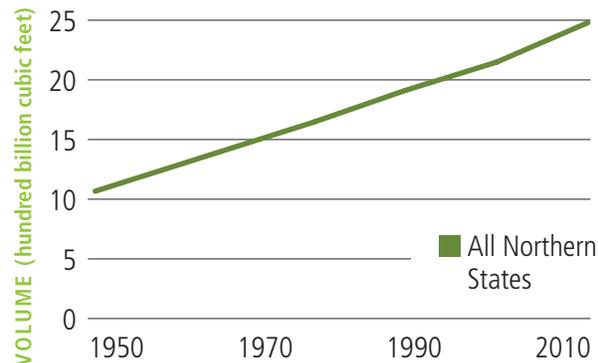
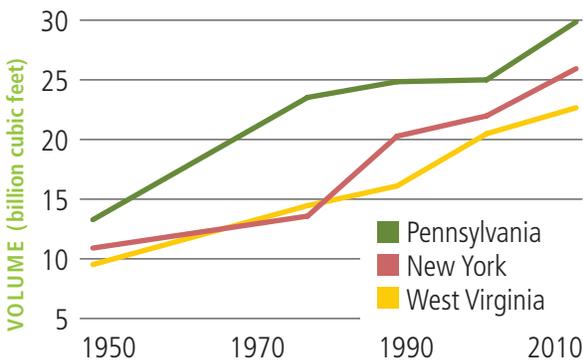
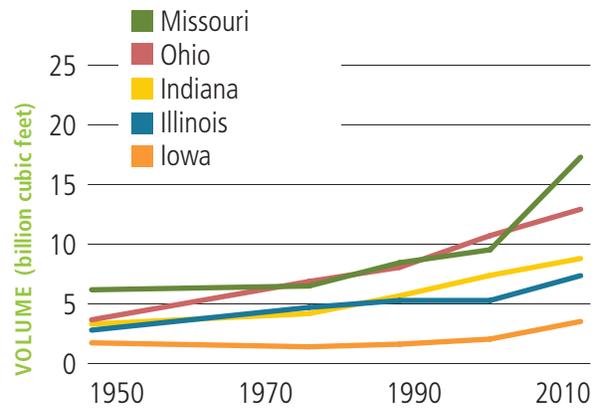
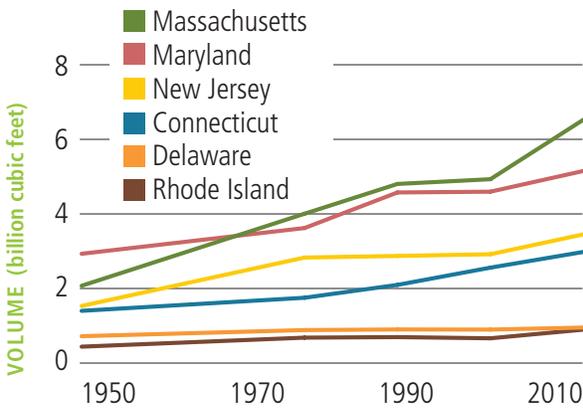
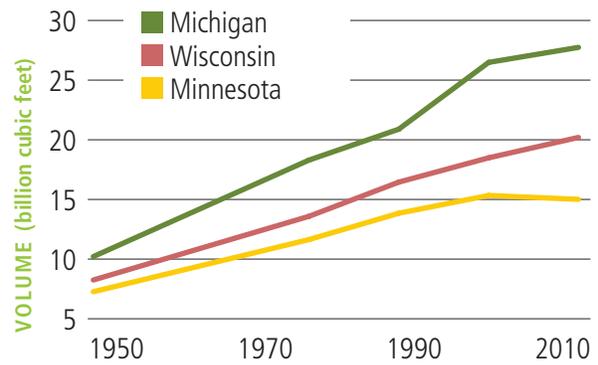
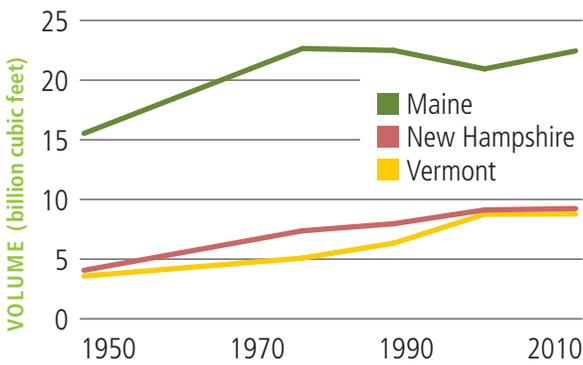
FIGURE 5

Proportion of timberland by owner group for the Northern States.



FIGURE 6

Growing-stock volume on timberland by Northern State, 1953 to 2007
(Smith et al. 2009).



Key Findings for Criterion 4:

CONSERVATION AND MAINTENANCE OF SOIL AND WATER RESOURCES

- A potentially serious soils-related forest health threat is increasing soil acidity and associated decreasing soil calcium reserves along with increasing potentially toxic levels of exchangeable aluminum. This soil condition is strongly related to atmospheric acid deposition.
- Forests protect the soil both directly and indirectly from wind and water erosion. Wind erosion is rare in wooded areas, because they are protected by forest canopy, strong soil tree root anchor support, and forest floor mulch (tree litter).

- Soil compaction is not a widespread problem on forested lands and is largely confined to trails (walking, biking, hiking, equestrian, and motorized) and forest harvest operations.
- Across the North, 48 percent of the water supply originates on the forest lands that cover 42 percent of the region. About 94 percent of the water that originates from forests comes from State and private forest lands (Fig.8).
- Forests in the North have the capacity to supply about 280 billion m³ (226 million acre-feet) of water annually.
- The ability of a watershed to produce clean water increases with increasing proportion of forest cover.

- Many northern watersheds have water quality problems, especially near major metropolitan areas (Table 1).

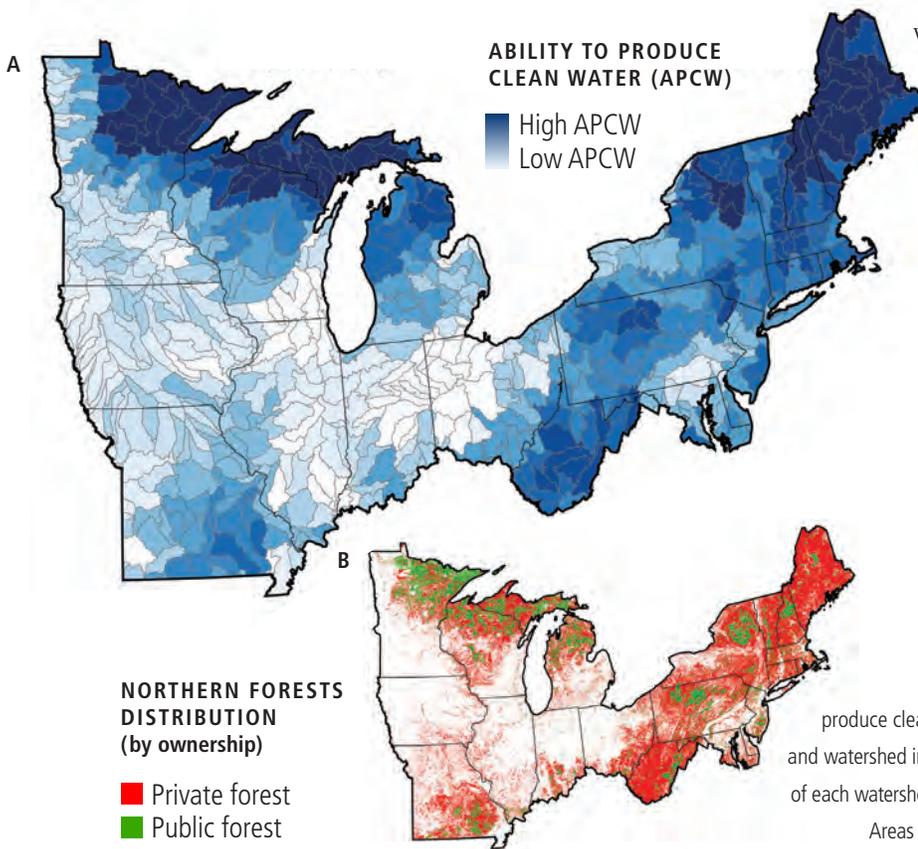


FIGURE 8

(A) Relative ability of 540 northern watersheds to produce clean water, represented by an index of water quality and watershed integrity that characterizes the biophysical condition of each watershed (Barnes et al. 2009, Homer et al. 2004, Protected Areas Center 2010); and (B) forest cover and ownership.

Key Findings for Criterion 5:

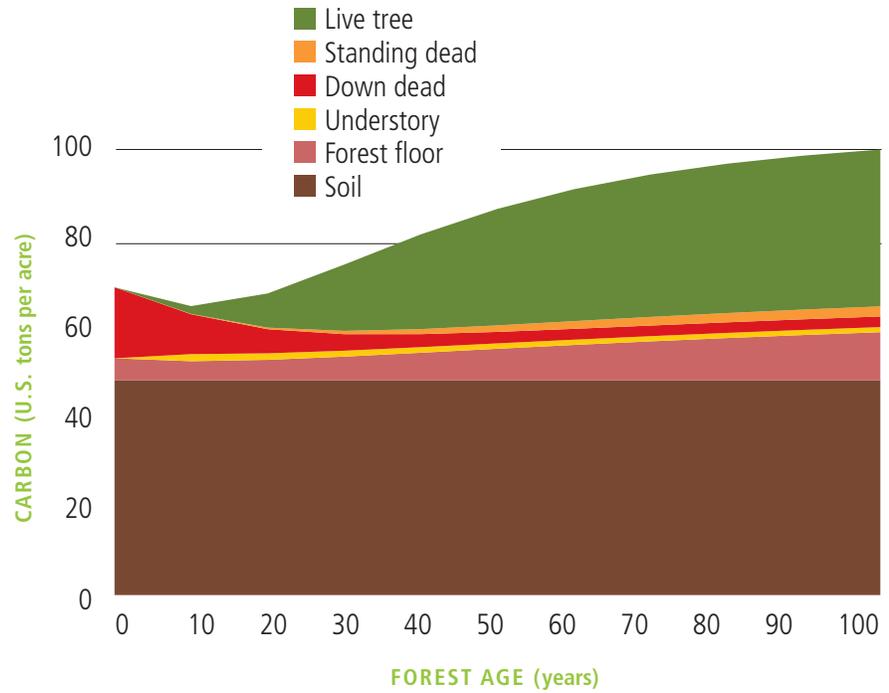
MAINTENANCE OF FOREST CONTRIBUTIONS TO GLOBAL CARBON CYCLES

- Through photosynthesis, trees pull carbon dioxide, a greenhouse gas, from the atmosphere and sequester it in wood and other tree parts.
- Forests sequester large amounts of carbon in soil organic matter and in the wood of living trees. As forests grow over time the amount of sequestered carbon increases (Fig. 9).
- The total amount of sequestered carbon in U.S. forests is equal to approximately 27 years of carbon dioxide emissions for the U.S.
- The annual net increase in carbon sequestered in U.S. forests due to tree growth is equivalent to about 10 percent of the annual emissions of carbon dioxide and associated greenhouse gasses.
- When trees are harvested and converted to wood products, the carbon in those products remains sequestered until they eventually decompose or are burned (Table 1).
- Using woody biomass to replace fossil fuels for energy production can reduce the release of carbon from the fossil fuels that would be used instead (Fig. 10).
- In 2007, the equivalent of 2 percent of the energy consumed in the United States came from wood combustion by industrial (1.3 percent), residential (0.4 percent), utility (0.2 percent), and other (0.1 percent) users.
- Less than 1 percent of U.S. electric power is generated from wood.



FIGURE 9

When and where carbon occurs in a typical forest—a composite summary for all northern forests showing average carbon by forest age and forest component; note that about 16 percent of live tree carbon is coarse roots (VanDuesen and Heath 2009).



COAL OFFSETS FROM BIOMASS (tons of carbon dioxide per year)

- Under 1,100
- 1,100 to 28,000
- 28,001 to 55,000
- 55,001 to 110,000
- Over 110,000

FOREST BIOMASS (tons per acre)

- 0
- Under 75
- 75 to 125
- 126 to 200
- 201 to 350
- Over 350

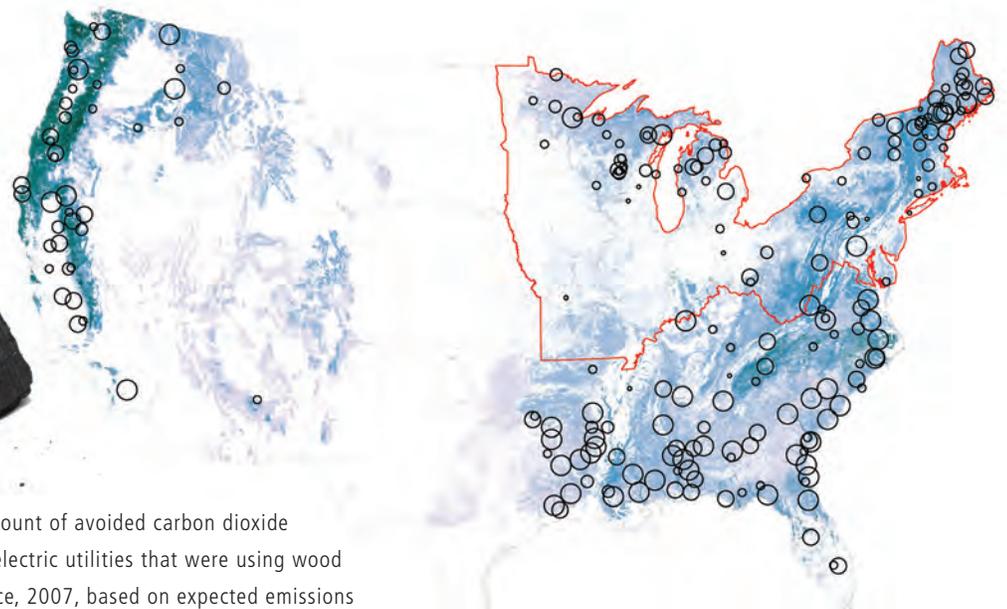


FIGURE 10

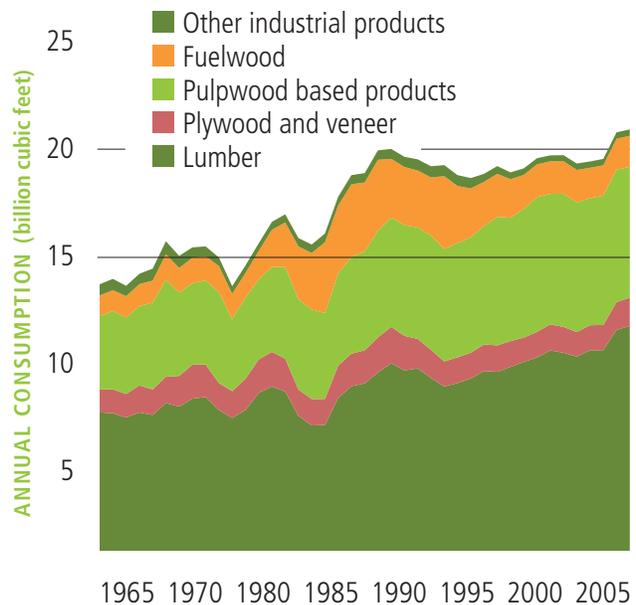
Location and amount of avoided carbon dioxide emissions from electric utilities that were using wood as a power source, 2007, based on expected emissions from using coal. (USDA FS 2011e)

Key Findings for Criterion 6:

MAINTENANCE AND ENHANCEMENT OF LONG-TERM MULTIPLE SOCIOECONOMIC BENEFITS TO MEET THE NEEDS OF SOCIETIES

- Estimated per capita consumption of wood products in the Northern States is 71 cubic feet. A growing population will increase total demand for wood products (Fig. 11).
- Northern forests are a major source of wood products, but imports are expected to continue to supply a sizeable amount that is consumed (Fig. 12).
- Most harvested wood is from hardwood species.
- Primary wood products manufacturing in the North had an estimated added value to the economy of \$52 billion or 41 percent of the \$124 billion value added nationally in this sector.
- From 2002 to 2006 investment in wood products manufacturing increased while investment in pulp and paper production declined.
- In the Northern States 441,000 workers are employed in forest management, logging, forest products, and pulp and paper industries. This is about 40 percent of the 1.1 million employees nationally in these industries.
- Wages for forestry jobs vary with large differences among States, but the average wage for the region is close to the national average.
- The number of injury cases recorded by the forestry and logging, wood product manufacturing, and pulp and paper industries has declined in recent years.
- Logging is the most risky forestry job. The fatality rate in the Northern States is close to the national average.
- Common nontimber forest products in the region include edibles (such as maple sap, nuts, berries, and mushrooms) and decorative materials (such as floral items, boughs, cones, vines, moss, and lichens).

FIGURE 11
U.S. timber products consumption by year and product class (Howard 2007).



- The North is the source of nearly all U.S. commercial maple syrup production.
- The most common nature-base recreational activities in northern forests are walking for pleasure; family gatherings; viewing/photographing scenery, wildlife, flowers; picnicking; sightseeing; and driving for pleasure (Table 1).

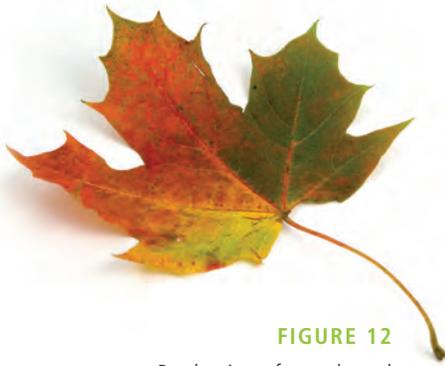
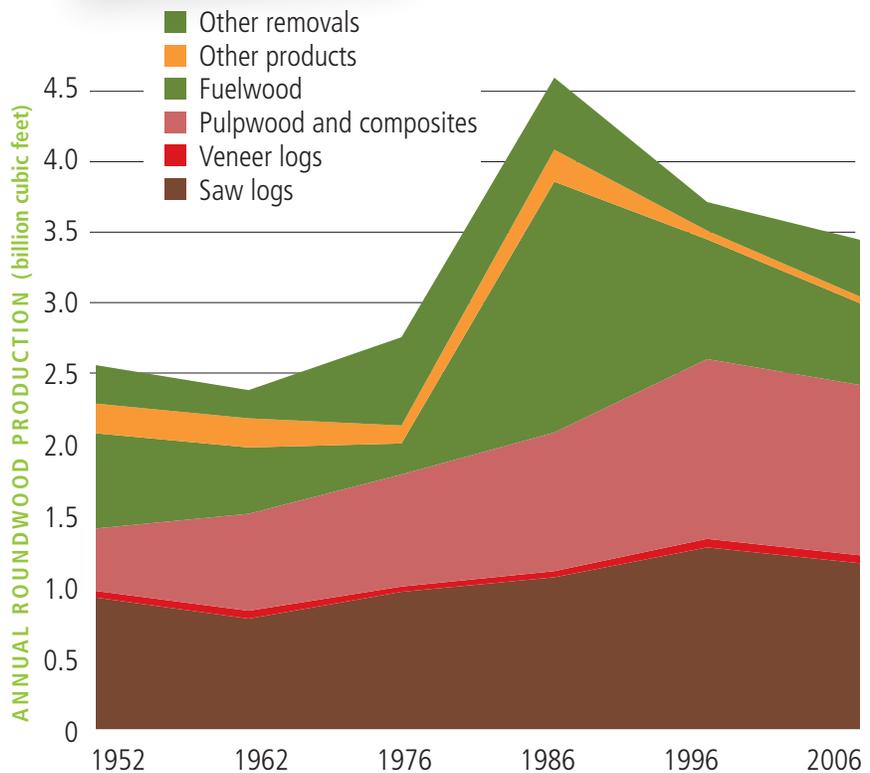


FIGURE 12
Production of roundwood products in the Northern States, 1952 to 2006 (Smith et al. 2009).



Key Findings for Criterion 7:

LEGAL, INSTITUTIONAL, AND ECONOMIC FRAMEWORK FOR FOREST CONSERVATION AND SUSTAINABLE MANAGEMENT

- Sixteen percent of northern forest land is protected (Fig. 13).
- Each Northern State recently completed a Forest Action Plan (Fig. 14).
- State and Federal agencies support forest planning on private forest lands.

- Just over half (11 of 20) of the Northern States require forest-related planning, and nearly all States require periodic planning or assessment for other natural resources or activities.
- Best practice codes, sometimes referred to as best management practices, represent society's collective wisdom about protecting the environment during land management operations like harvesting and road building. These have been adopted across the Northern States, but enforcement and monitoring vary widely.

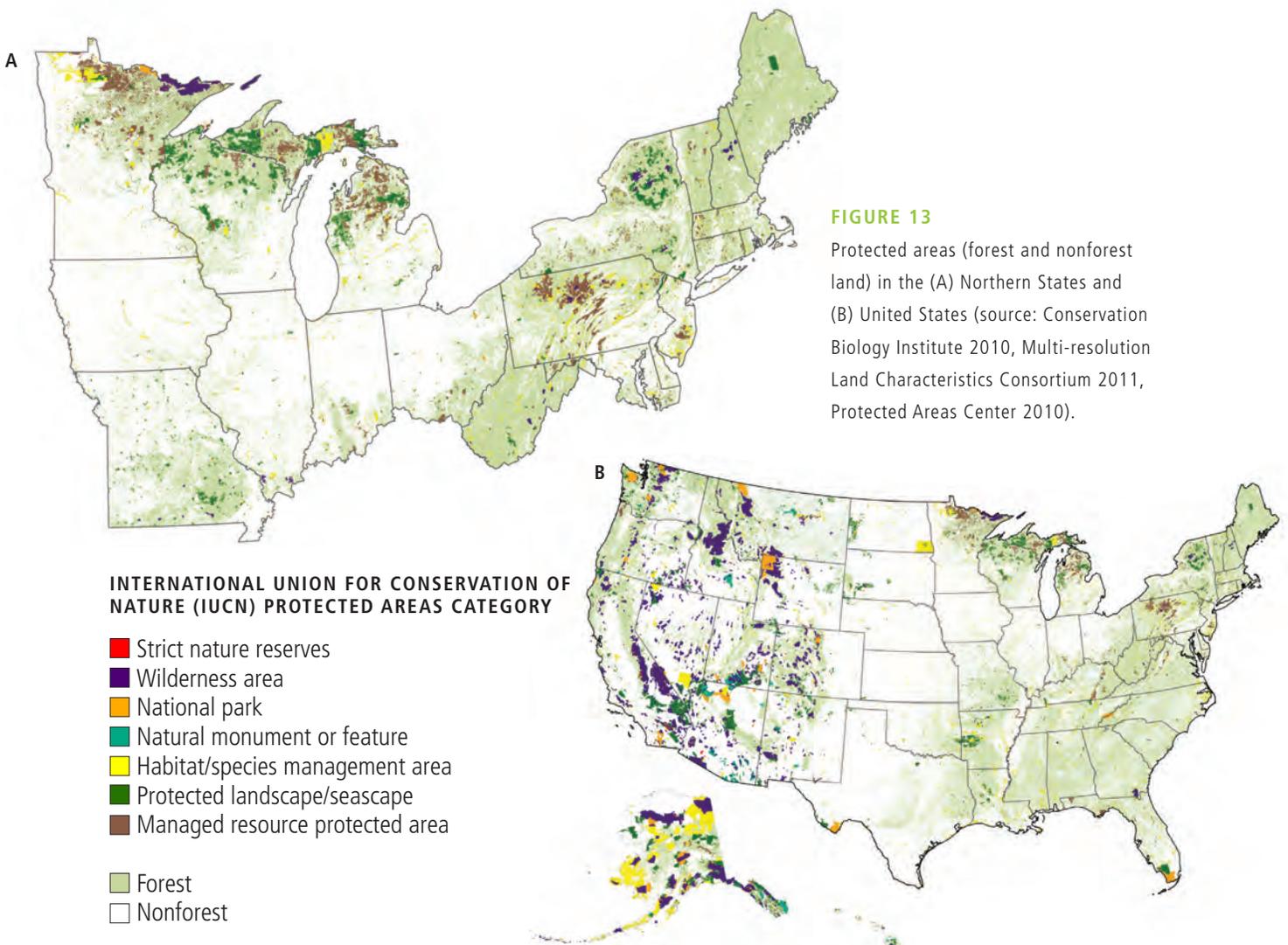


FIGURE 13

Protected areas (forest and nonforest land) in the (A) Northern States and (B) United States (source: Conservation Biology Institute 2010, Multi-resolution Land Characteristics Consortium 2011, Protected Areas Center 2010).

- Conserving special forest values in the North, where private and non-Federal ownership account for 92 percent of forested land, requires coordination between many owners. Agreements that transfer, trade or sell some of these property rights (for example, development rights) are key to conservation schemes in landscapes with mixed ownerships.

- Continuing parcelization and turnover in ownership is a concern, because they jeopardize previous arrangements and coordination of resource management (Table 1).

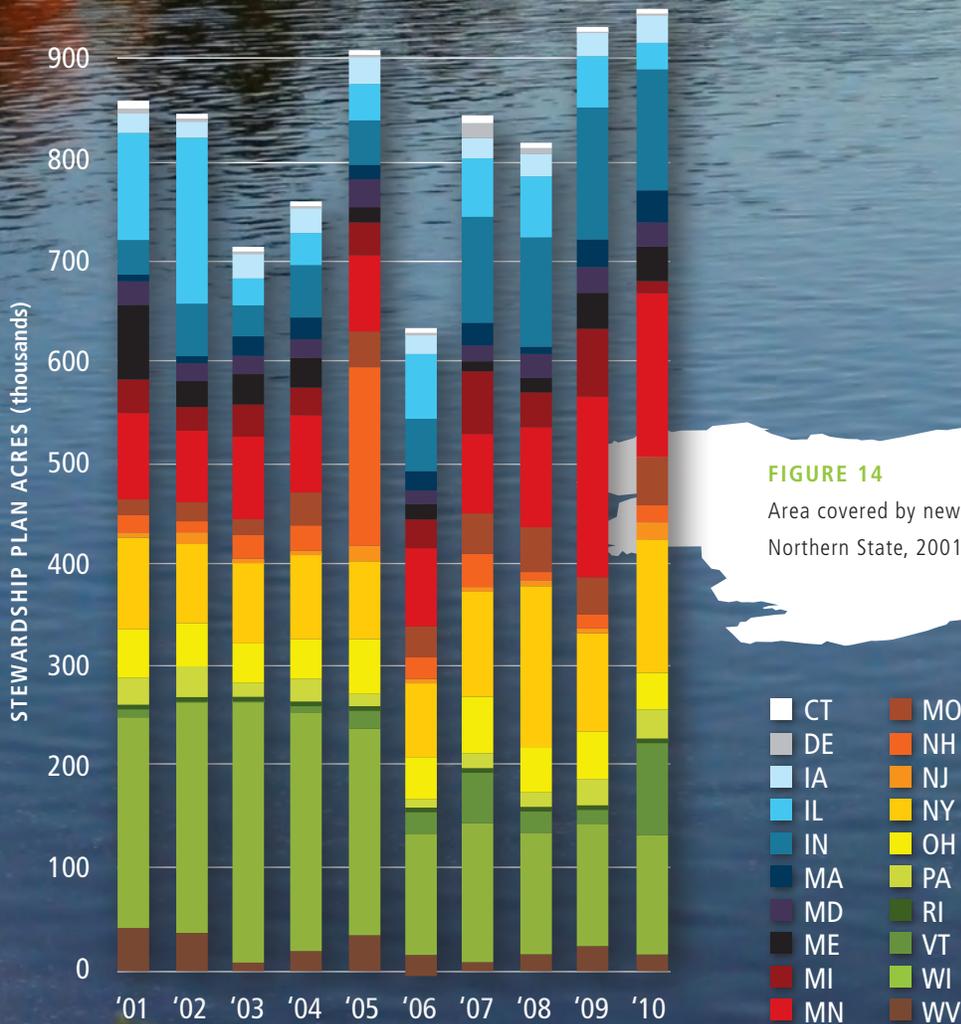


FIGURE 14

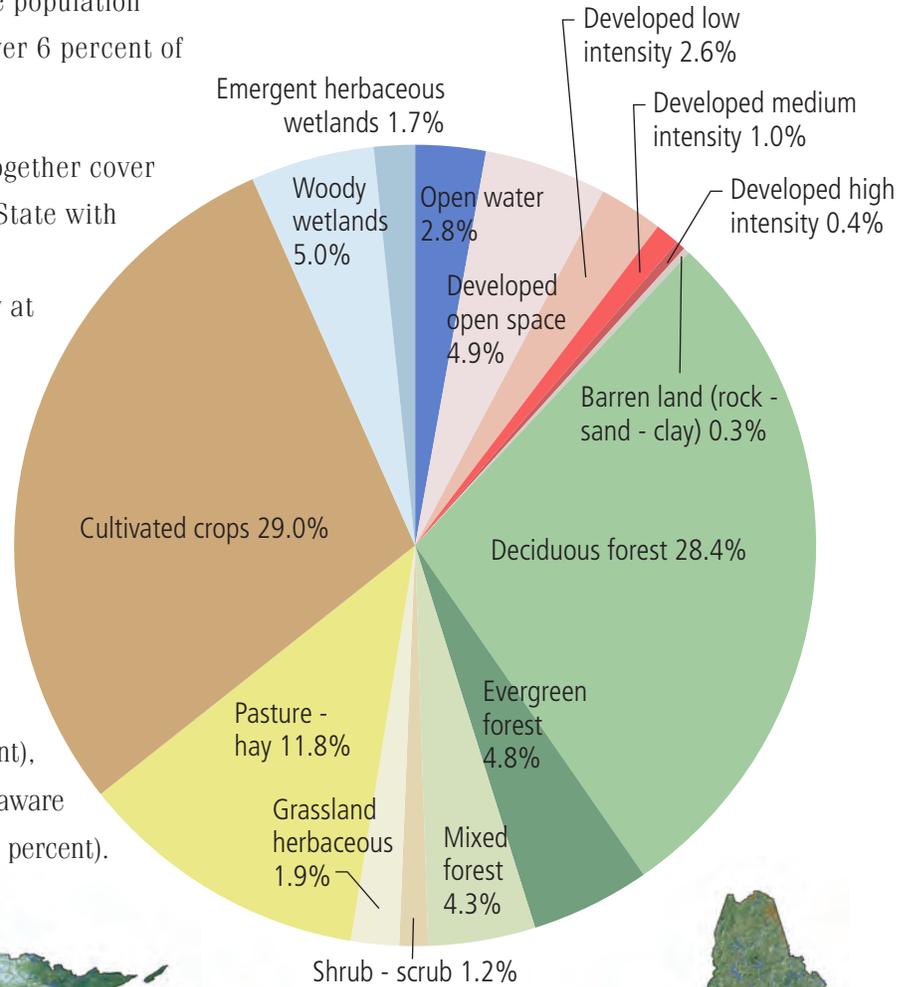
Area covered by new or revised stewardship plans by Northern State, 2001 to 2010.

Key Findings for Criterion 8:

URBAN AND COMMUNITY FORESTS

- In the North, 80 percent of the population lives in urban areas which cover 6 percent of the region's land base.
- Urban and community lands together cover 8.5 percent of the North. The State with the highest percent urban or community land is New Jersey at 44.2 percent; the lowest is Vermont at 2.9 percent (Fig. 15).
- Nationally, States with the greatest increase in percentage of urban land between 1990 and 2000 were in the North: Rhode Island (5.7 percent), New Jersey (5.1 percent), Connecticut (5.0 percent), Massachusetts (5.0 percent), Delaware (4.1 percent), and Maryland (3.0 percent).

- Most of the urbanization in the North in the 1990s occurred in agricultural (42 percent) and forested (37 percent) areas.



LAND COVER

- Open water
- Developed, open space
- Developed, low intensity
- Developed, medium intensity
- Developed, high intensity
- Barren land (rock-sand-clay)
- Deciduous forest
- Evergreen forest
- Mixed forest
- Shrub-scrub
- Grassland-herbaceous
- Pasture-hay
- Cultivated crops
- Woody wetlands
- Emergent herbaceous wetlands

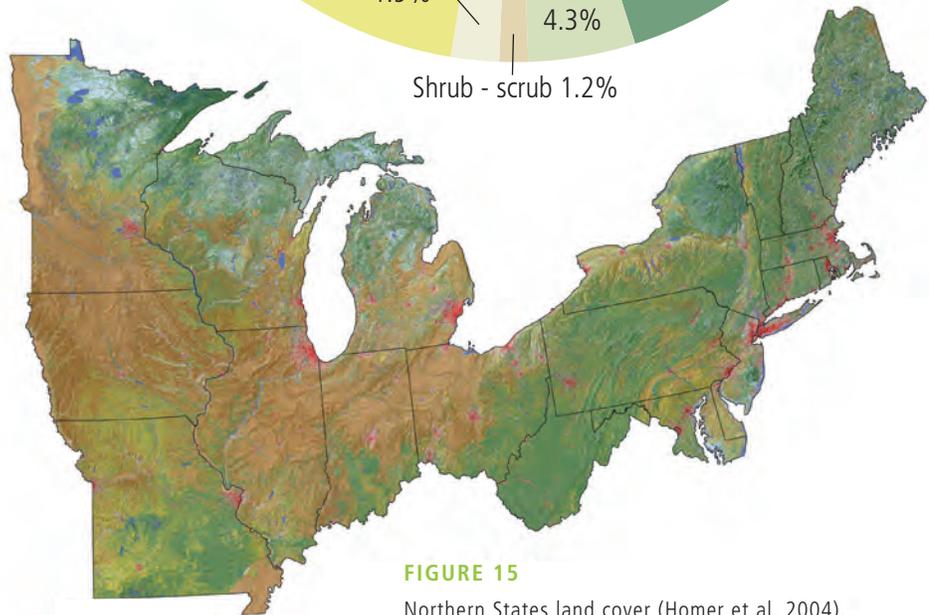


FIGURE 15

Northern States land cover (Homer et al. 2004).

- Of the 11 conterminous States that had greater than half of all urban development occur within forests in the 1990s, seven were in the North, including the top two (Rhode Island and Connecticut).
- Overall tree cover in the North is 47 percent, with the highest percent tree cover in New Hampshire (89 percent) and the lowest in Iowa (10 percent).
- Within urban or community lands in the North, tree cover averages 39 percent while impervious cover averages 20 percent. Tree cover in urban or community lands ranged from a high of 67 percent in Connecticut to a low of 19 percent in Iowa.
- Tree cover in urban or community areas provides many and valuable ecosystem services (Table 1).





*Autumn colors surround
the Glade Creek Grist Mill in West Virginia*

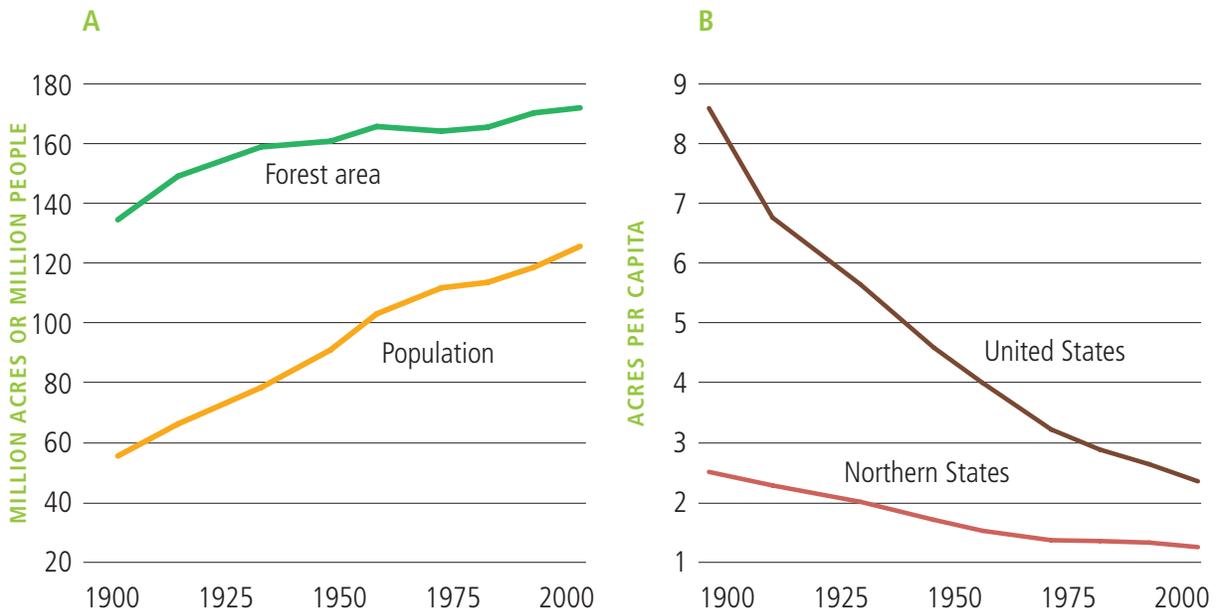
Summary and Synthesis

A regional assessment can provide the context and data needed to facilitate discussions about issues related to sustainable forest development. Ultimately it is the work of society to choose among options, make tradeoffs among desirable outcomes, and select the most effective or most equitable solutions. Those choices are implemented through discourse, legislative and rule-making processes, purchases made and forgone, opinions expressed, and investments made. The many issues affecting northern forests are interrelated, and so are approaches to achieving desired outcomes. The following sections summarize some of the interrelationships, interactions, and drivers of change that affect northern forests.

FORESTS AND PEOPLE TOGETHER

The abundance of northern forests comes with an abundance of people. Over the past century, the North's population increased at a faster rate than forest land, and this resulted in a gradual decline in forest area per capita from 2.6 to 1.4 acres (Fig. 16). However, changes in forest area per capita have been much greater for the rest of the United States, and this has substantially closed the gap in forest area per capita between the North and the country as a whole.

FIGURE 16
Forest area and population in the Northern States (A), and forest area per capita in the Northern States and the United States (B) (Smith et al. 2009, and U.S. Census Bureau 2010).



For Discussion

- What is a desirable mix of commodities, amenities, and ecosystem services from the 172 million acres of northern forest land, and to what extent can producing that mix simultaneously help sustain forest health and diversity?

What is utterly remarkable about northern forests is that their total area has increased over the last century, despite a 138 percent increase in population. However, the area of forest land appears to have peaked, or nearly so. Pressures to fragment forests, subdivide forest ownerships, and convert forests to developed uses have been substantial and are expected to continue. From 1990 to 2000, expanding urban development in the North subsumed 4 million acres of land, 37 percent of which had been forested.

Some negative consequences of population pressure on forests notwithstanding, the proximity of people to forests creates some unique opportunities in the North. Urban trees and forests are especially important to quality of life for the 80 percent of residents who live in northern urban areas. The North's rural forests are accessible to and serve many people. And energy or biofuels produced from wood are close to large numbers of energy consumers.

INVASIVE SPECIES

The impacts of invasive species are enduring. The gypsy moth, Dutch elm disease, and chestnut blight have each afflicted northern forests for more than 70 years. The emerald ash borer, Asian longhorned beetle, hemlock woolly adelgid, and the thousand cankers disease of walnut are spreading. Autumn olive, multiflora rose, and bush honeysuckle are well entrenched. Past experience suggests that (1) despite their best efforts, forest managers will lose battles with some current invasive species and with others yet to arrive; and (2) when a new invasive species gets a foothold, management and mitigation efforts will be long, costly affairs.

Ongoing, active management of urban, community, and rural forests is one method of identifying, resisting, mitigating, and managing invasive species. The fact that a small proportion of rural forest acreage is actively managed limits opportunities to counteract the threat of invasive species through early identification, preemptive actions to reduce risk, or rapid response to treat affected trees and forests.

For Discussion

- To what extent can efforts to manage invasive species complement other objectives such as maintaining overall forest health, maintaining native species diversity, managing forests to increase resilience to future forest disturbances, and utilizing wood harvested in the process?

BIODIVERSITY

Almost 15 percent of forest-associated species in the North are considered at some risk of extinction or extirpation. One approach to maintaining forest biodiversity is to create diverse, healthy forests that support many species, monitor species of conservation concern, and adapt management practices as necessary to sustain rare habitats and rare or declining species. This is done in a systematic way on many public forests and some private forests. State Forest Action Plans (USDA FS and NAASF 2011) and wildlife action plans (Association of Fish and Wildlife Agencies 2011) address biodiversity issues in multiple ways, including management emphasis on priority conservation areas.

On a regional level, analyses of biodiversity require additional emphasis. For example, as an artifact of past management and disturbance across the region, northern forests are clustered in the 40- to 80-year-old age classes with relatively few forests younger than 20 years or older than 100 years. Given current rates of forest disturbance and regeneration, old forests will likely increase in abundance as forests across the region increase in age, but the area of young (early successional) forests—and associated habitats—will likely remain small. This has far-reaching implications for the abundance of wildlife species that depend on early- or late-successional forest habitats and, thus, for forest biodiversity in general.

Forest age-class diversity is among the simplest measures of forest structural diversity and habitat diversity, and it is a measure for which there are excellent data at local, State, and regional scales. Yet the lack of forest age-class diversity has received relatively little attention in discussions of forest sustainability across the North.



For Discussion

- How would management aimed at increasing forest age-class diversity affect wildlife diversity?



For Discussion

- To what extent can production of wood and pulp products enhance opportunities to achieve other goals such as improved forest health, increased biodiversity, increased employment, or increased access to renewable energy?



CONSUMPTION AND PRODUCTION OF WOOD AND PULP PRODUCTS IN THE NORTH

Consumption of wood and pulp products in the form of lumber, paper, plywood, composite panels, and pallets is about 71 cubic feet of wood per person annually, or roughly 8.8 billion cubic feet for the 124 million people who live in the Northern States. Total U.S. wood and pulp products consumption is about 21 billion cubic feet. The U.S. has long been a net importer of these products; in 2005 net imports amounted to 6 billion cubic feet.

In 2006, about 3.5 billion cubic feet of wood and pulp products were produced in the North (Fig. 9). This is a relatively small proportion of the total U.S. production (19 percent) or consumption (17 percent) of wood and pulp products given that the North includes 32 percent of U.S. timberland.

Timber is harvested and processed to meet demand generated by consumers. Where timber harvesting occurs—be it the North, elsewhere in the United States, or elsewhere in the World—it has impacts. It changes forest structure, species composition, habit characteristics, the quantity of sequestered carbon, water and soil characteristics, recreation opportunities and other factors. Timber harvesting in conjunction with a management plan can create opportunities to simultaneously address perceived problems with insects, diseases, invasive species, or biodiversity. A viable forest products industry can be an important source of employment and economic support for rural communities. Declines in forest products output can remove those opportunities.



CARBON SEQUESTRATION AND CLIMATE CHANGE

Concerns about climate change focus on the concentration of atmospheric carbon dioxide and other greenhouse gases, which in turn is affected by the amount carbon that is sequestered in forest ecosystems. Potential effects of climate change on forest ecosystems continue to be studied, including research that forecasts how the spatial distributions of tree species and of wildlife are likely to shift under alternative climate change scenarios.

Northern forests contain vast quantities of sequestered carbon in soils, live trees, dead trees, and down logs. As forests grow, they accumulate carbon in woody biomass, but the quantity of carbon annually sequestered from the atmosphere by all U.S. forests is only about 10 percent of the quantity of U.S. carbon emissions from burning fossil fuels and other sources. Management practices that enable forests to sequester more carbon annually are likely beneficial, but their impact will be relatively small compared to total carbon emissions from all sources. Some have suggested that an effective way of reducing atmospheric carbon would be to use wood for energy (heat, electricity, liquid fuels), thereby offsetting carbon released from the fossil fuels and creating opportunities for carbon sequestration in regenerating forests (Malmshemer et al. 2008).



For Discussion

- How and where do management practices for addressing climate change converge with other complementary management objectives?

Other actions that improve the carbon balance by increasing carbon sequestration or decreasing carbon emissions include keeping forests as forests, planting nonforest areas with trees (afforestation), choosing to use durable wood products that sequester carbon during their useful life, and conserving energy. Such actions are important components of a strategy to reduce net greenhouse gas emissions.

BIOENERGY

The motivation to increase utilization of woody biomass for energy is directly related to concerns about greenhouse gas emissions, carbon sequestration, climate change, and our dependence on fossil fuels. Using woody biomass instead of fossil fuels to produce energy has the potential to reduce net carbon emissions. The most efficient strategies for managing carbon may be those that never release it to the atmosphere in the first place—conservation and renewable alternatives to fossil fuels. Knowledge and technologies continue to evolve on efficient ways to convert woody biomass into energy while reducing net greenhouse gas emissions.

For Discussion

- What other management interests and objectives align with producing forest-based bioenergy?

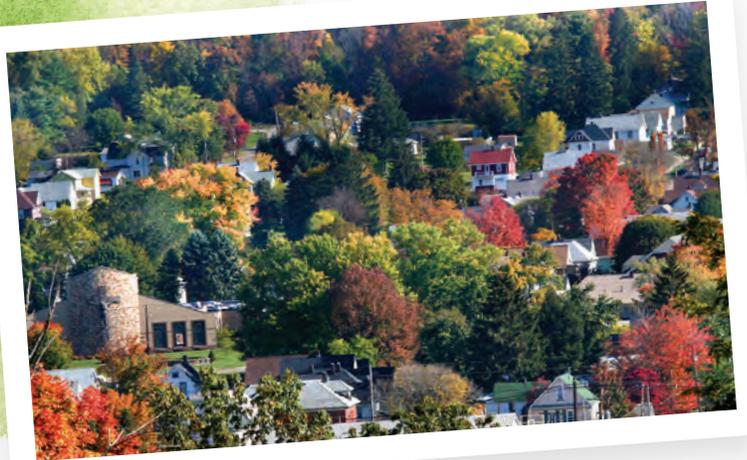
The total amount of forest biomass in northern forests is immense, and the annual rate of biomass accumulation is much higher than the current rate of harvesting. Biomass harvesting for energy production presents opportunities to simultaneously meet (or hinder) other conservation objectives.

CAPACITY FOR FOREST MANAGEMENT

Forest management is virtually the only process available for reducing the undesirable impacts of forest disturbances or for increasing the output of desirable forest products, amenities, and ecosystem services. Outputs of wood products and biomass obviously depend on forest management practices. Less obvious, perhaps, is the importance of active forest management in restoring savanna and woodland habitats, providing habitat for desirable wildlife species, sustaining forest biodiversity, increasing forest carbon sequestration, or sustaining forest health. Northern forests are persistently afflicted by severe weather, invasive species, native insects, diseases, wildfire, and climate change. The undesirable impacts of these disturbance agents can be partially mitigated through proactive management to promote forest health and increase resilience. Reactive management following large-scale disturbance events can speed forest recovery and salvage forest products. Active forest management requires motivation and adequate resources on the part of forest owners as well as adequate numbers of skilled and equipped specialists to prescribe and implement treatments—both of which are lacking throughout much of the region. Only 4 percent family forest owners report that they have a written management plan, and they tend to be the owners with larger forest acreages; collectively they manage about 16 percent of the total family forest area in the region (Butler et al. 2010).

For Discussion

- To what extent can forest management be more widely and regularly applied in the North to help forest owners and managers pursue multiple conservation objectives?



URBAN AND COMMUNITY FORESTS

Most people in the Northern States—80 percent—live within urban areas that cover only 6 percent of the region’s land base. However, urban areas are expanding at a rate of nearly 4 million acres per decade, and 1.5 million acres of that expansion spreads into land that was formerly classified as forest. This expansion of housing and other development changes the character of forests in important ways (Fig. 17).

Trees cover nearly 40 percent of urban or community lands. Because of their proximity to people, such trees are highly valued and are relatively expensive to treat or replace if attacked by insects or diseases. Parks, preserves, riparian zones, and other forested areas can provide unique habitats and recreation opportunities within urban or community areas. Thus, some people find expansion of urban and community areas into forest land desirable. However, human populations in and around urban and community lands along with parcelization, fragmentation, and expansion of impervious surfaces can reduce tree cover, degrade air and water quality, and alter species composition and biodiversity. These effects are often considered undesirable consequences of urban and community expansion.

For Discussion

- What options are available to manage urban and community expansion so that desirable forest-associated benefits are maintained while sustaining the needs of a growing human population?

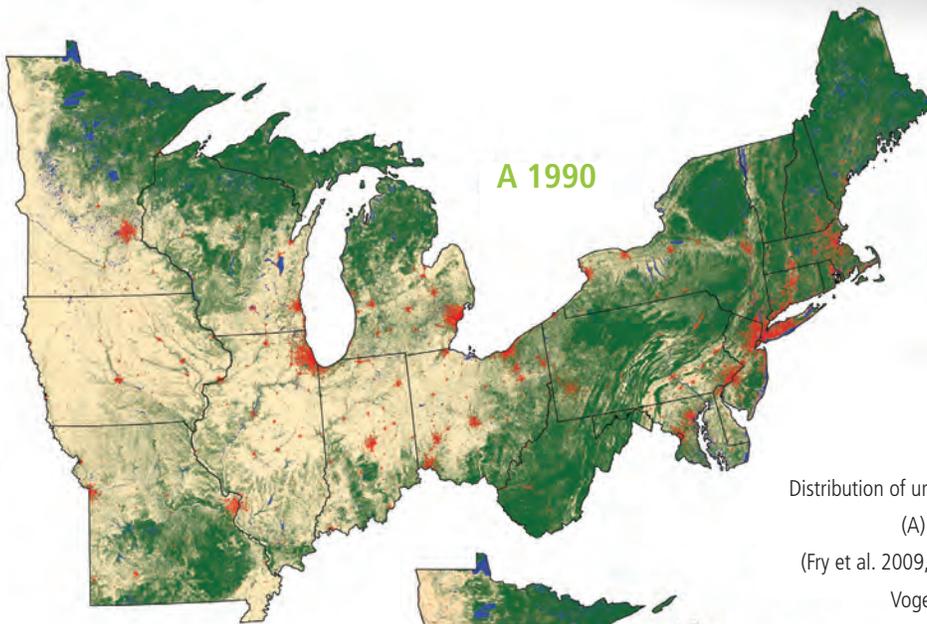
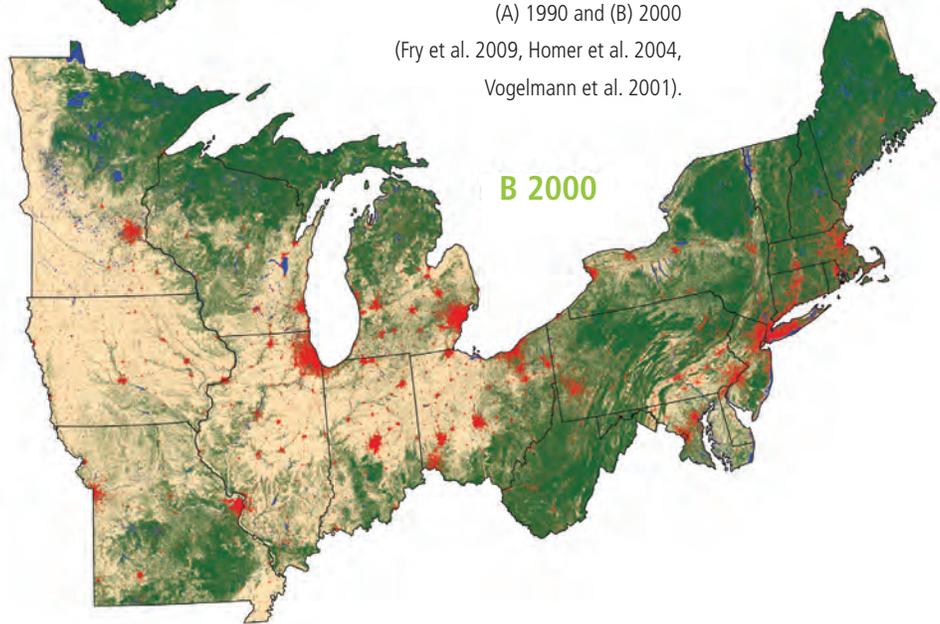
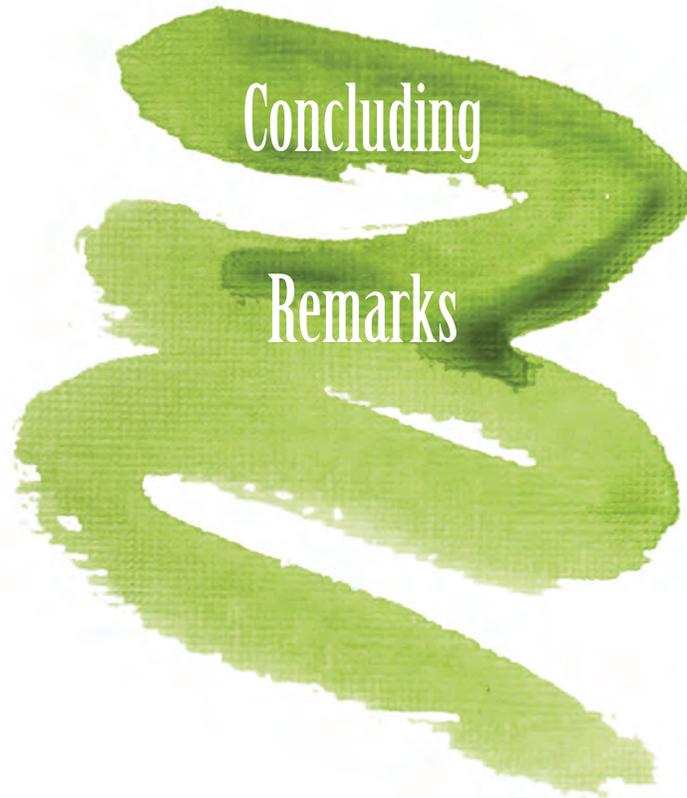


FIGURE 17

Distribution of urban and forest land
 (A) 1990 and (B) 2000
 (Fry et al. 2009, Homer et al. 2004,
 Vogelmann et al. 2001).

- Nonforest
- Water
- Urban
- Forest





Concluding Remarks

This executive summary provides only a brief overview of forest conditions in the North. The full report (Shifley et al. 2012) provides much greater detail for individual states with the aid of 39 tables and 68 figures. Numerous maps provide a geographic context for characteristics that vary spatially across the region. The table beginning on the following page summarizes additional information from the full report. Efforts to address many of the pressing forest resource issues in the North can benefit from this regional perspective. It also complements State Forest Action Plan (USDA FS and NAASF 2011).

Development of policies and practices supportive of forest sustainability requires the capacity to view the consequences of management decisions (including no action) across multiple spatial scales and multiple timeframes. Most forest management is implemented on the ground an acre or a stand at a time, but views of the forest from larger spatial scales and longer timeframes are necessary to understand the cumulative effects of thousands or millions of individual management actions. Relevant spatial scales include landscapes, ecoregions, watersheds, States, multi-State regions, and nations. Relevant timeframes include a few decades to more than a century. Although all definitions of forest sustainability are partially subjective, the full report identifies some specific conditions and trends that appear consistent with forest sustainability and some that do not. More importantly, it provides necessary facts, figures, and maps for ongoing, detailed discussions about the current and future sustainability of northern forests.

Table 1—Summary of northern forest sustainability condition ratings for forest sustainability indicators. Current conditions and recent trends are rated separately (when possible). Condition ratings represent the best judgment of the authors based on evaluations of each indicator with respect to forest sustainability for the region as a whole. People with different perspectives or people examining different areas within the region are likely to differ in the condition ratings they would assign to a given indicator.

No.	Indicator	Current condition rating ^a	Recent trend condition rating ^a	Rating explanation
1	Forest area			Forests cover 42 percent of the land, an increase of 38 million acres over the past 100 years, despite population growth and urban expansion. In recent decades forest area has ceased to increase in many States and has declined in some.
2	Forest ownership			Public forest lands constitute a small share of the region as whole, but individual States vary greatly in their proportion of public land. A mix of public and private ownerships is usually considered desirable because public and private forest land managers often (but not always) differ in their management objectives and their capacity to provide forest products, amenities, and ecosystem services. (See also Parcelization, item 7.)
3	Protected forest			About 16 percent of forests (27 million acres) are under some category of protection. Compared to the rest of the United States, protected northern forests are concentrated in the least restrictive protected categories. Most protected areas are on public land, but conservation easements and similar instruments are increasingly used to expand the area of protected private forest land. Some habitats of high conservation interest (e.g., floodplains or migration corridors) are underrepresented in current protected areas.
4	Forest cover types			Forest cover types are the result of past disturbances and management activities. Changing the mix is a long-term endeavor. Loss of pine forest acreage relative to historical levels has reduced forest biodiversity in some areas. The ongoing transition of oak dominated forest to maple-dominated forest continues, at the expense of wildlife habitat quality. As long as native forest cover types are widely distributed across the landscape within their historic ranges there is little basis to judge the condition positive or negative.

^a Highly positive Positive Neutral Negative Highly negative

Table 1 continued

No.	Indicator	Current condition rating ^a	Recent trend condition rating ^a	Rating explanation
5	Forest age classes			Past patterns of harvesting and wildfire suppression have left the North with relatively little young (early successional) forest or old forest, but with relatively abundant forest in the 40- to 80-year age classes. Lack of age class diversity indicates a lack of forest biodiversity. With current rates of disturbance, the area of old forests is increasing over time, but the area of young forests is not.
6	Fragmentation			Northern forests continue a decades-long trend of fragmentation. However, interpretation of this metric differs with timeframe and scale; for example, over the past century unproductive farms abandoned in the first half of the 20th century have reverted back to forest via natural succession—a process that has contributed substantially to maintaining a stable forest area. (See also Forest area, item 1.) In recent decades, however, expansion of urban, suburban, and exurban areas has fragmented millions of acres of forest land.
7	Parcelization			The average size of family forest ownerships continues to decrease, reaching a regionwide average of 26 acres in 2006. As forest ownerships become smaller, the economic viability of forest management decreases, and addressing large-scale forest management issues becomes more difficult.
8	Number and status of native forest-associated species			Many forest-associated species are at risk or have been previously extirpated. Tools to inventory and monitor forest associated species are improving, but a full inventory of forest associated species is lacking. Ongoing trends in forest fragmentation and conversion of forest to other uses are usually considered detrimental to native forest-associated species. (See also Fragmentation and Urban and community land, items 6 and 34.)
9	Timberland			The region has a high proportion of timberland relative to total forest land, and that has changed little in recent decades.

^a ● Highly positive ◐ Positive ● Neutral ◐ Negative ● Highly negative

Table 1 continued

No.	Indicator	Current condition rating ^a	Recent trend condition rating ^a	Rating explanation
10	Wood volume			Wood volume is abundant and has increased substantially in the past 50 years. Invasive species have greatly reduced the wood volume of targeted tree species in some locations.
11	Wood growth and removals			Wood growth far exceeds removals and has done so for decades. This is locally sustainable but it may represent lost opportunities for forest-associated employment or may result in transfer of harvesting impacts to forests outside the region.
12	Planted forests			Compared to the rest of the United States, the area of planted forest is low. Planted forests often have greater productivity per acre than native forests, but converting native forests to plantations generally decreases biodiversity.
13	Tree mortality			The current rate of tree mortality across the region is relatively low. However, increasing mortality associated with invasive species is a concern. (See also Insect and disease incidence and risk, item 15.)
14	Indicators of forest damage on standing timber		N/A	Only a small percentage of trees have damage or defects. Temporal trends in damage indicators are not available.
15	Insect and disease incidence and risk			Old and new invasive species are causing severe localized mortality for some tree species and widespread chronic defoliation or mortality for others. Controlling insects and diseases or managing forests to adapt to them is often a costly, long-term endeavor.
16	Soil quality		N/A	Regional inventories show the proportion of bare forest soil and compacted forest soil to be relatively low. Excess aluminum can be toxic to trees and other plants under certain conditions. Many other soil characteristics (such as percent soil organic matter) are now routinely quantified for forest inventory plots, but whether levels are beneficial or detrimental to forest sustainability is debatable. For conserving soil, managing land for forest cover is generally considered preferable to other land uses. Trends in forest soil characteristics are poorly documented.

^a Highly positive Positive Neutral Negative Highly negative

Table 1 continued

No.	Indicator	Current condition rating ^a	Recent trend condition rating ^a	Rating explanation
17	Water supply and quality			Nearly half of the region's surface water supply originates from forest lands and most drinking water comes from surface water sources. Most rainfall and snowmelt in forests moves into streams through subsurface flows, accelerating nutrient uptake and contaminant absorption processes. Increasing forest area in the last century has benefited water quality, but the more-recent losses of forest land to urban development have not.
18	Carbon sequestered in forests			The quantity of sequestered carbon in forests generally increases as the volume of live trees increases. The volume of timber in the region has increased substantially in the past 50 years. (See also Wood volume, item 10.)
19	Carbon sequestered in forest products			Carbon is sequestered in forest products. Regionally about 1.5 billion cubic feet of wood is converted annually to long-lived products. Another 0.9 billion cubic feet is used to produce pulp and paper products. This is a substantial quantity of wood products and associated sequestered carbon, but it is below the region's capacity. Since 1986, the annual volume of roundwood products has decreased. (See also Wood volume and Wood growth and removals, items 10 and 11.)
20	Using woody biomass for energy			Annually about 0.6 billion cubic feet of wood harvested in the region is used for fuelwood (including residential heating). This is a small part of the region's energy needs, but utilization of woody biomass for energy is increasing. Use of fuelwood often offsets consumption of fossil fuels that would be used instead.
21	Consumption of wood and wood products			Consumption of wood products is about 71 cubic feet per capita. Per capita consumption is expected to remain stable or decrease slightly, but increases in population have and will continue to increase total wood products consumption.

^a Highly positive Positive Neutral Negative Highly negative

Table 1 continued

No.	Indicator	Current condition rating ^a	Recent trend condition rating ^a	Rating explanation
22	Value and volume of wood and wood products			The total value of primary wood product shipments from the region was \$112 billion in 2006, and associated wood products manufacturing provided \$52 billion of added value. But based on the rate of increase in total forest volume, the value and volume of wood products production appears to be below potential. (See also Wood volume, item 10.) Roundwood harvesting increased from 1952 to 1986, but has remained flat since.
23	Recovery or recycling of wood products			The national paper recovery rate is about 50 percent and has gradually increased in past years. Paper recovery is not tracked separately for the Northern States.
24	Nontimber forest products			Increased attention is being given to quantifying the value of nontimber forest products. Utilization appears to be below potential. Edible and decorative nontimber products are collected by about 10 percent of family forest owners. Sales of maple syrup produced in the region have increased sharply in recent years and now exceed \$91 million, annually.
25	Revenues from forest-based environmental services			Values for forest-based environmental services have been difficult to quantify but are the focus of increased attention as potential sources of income.
26	Investments and expenditures in forest management, industries, services, and research			Investments in forest management are substantial in terms of total dollars, but stewardship plans only cover about 16 percent of private forest area not owned by the forest products industry. The largest industrial investments were in the pulp and paper sector. Active forest industries can increase understanding of and support for forest management. When adjusted for inflation, the combined U.S. Forest Service expenditures on management, State and private programs, and research in the region have declined slightly since 2005. Investments in management and certification by nongovernmental organizations are increasing in impact.

^a  Highly positive  Positive  Neutral  Negative  Highly negative

Table 1 continued

No.	Indicator	Current condition rating ^a	Recent trend condition rating ^a	Rating explanation
27	Employment in forest products industries			The region employs 441,000 workers in the forestry and logging, wood products, and pulp and paper industries, a steady decline since 2001. Total employment is probably less than the region's forest resources are capable of supporting. Stable employment opportunities in logging and forest products industries often benefit rural communities economically.
28	Wages, income, and injury rates in forest industries			Total wages in the forestry and logging, wood products, and pulp and paper industries are about \$19 billion annually. Since 2001, average wages have been flat. Injury rates are comparable to the national average and have been decreasing.
29	Recreation and tourism			Northern forests provide the equivalent of nearly 15 billion activity days of recreation. The number of activity days increases with the increasing population in the region. This creates opportunities for more people to interact with forests, but can result in conflicts over competing uses.
30	The importance of forests to people		N/A	The importance of forests to people extends beyond what can be extracted from forests to what they are. This can become a source of controversy if natural resource management actions threaten to change the character of places where people have formed strong attachments. There is a growing body of knowledge on this topic, but no basis for rating an overall trend.
31	Forest-related planning, assessment, and policy review; and opportunities for public involvement and participation in public policy and decisionmaking			All Northern States recently completed Forest Action Plans. States differ in many forest planning and public involvement policies, but coordination is increasing on regional forest planning and policy issues. (See also Investments and expenditures in forest management, industries, services, and research, item 26.)

^a ● Highly positive ● Positive ● Neutral ● Negative ● Highly negative

Table 1 continued

No.	Indicator	Current condition rating ^a	Recent trend condition rating ^a	Rating explanation
32	Best practice codes for forest management			Most States have some form of best practice codes or best management practices (BMPs) that address silviculture, water and soils, and wildlife or biodiversity. BMPs are optional in some States, but attention to BMPs and associated forest management issues has increased over the last decade. BMPs require ongoing revision to address emerging issues such as invasive species management or biomass harvesting.
33	Management of forests to conserve environmental, cultural, social, and/or scientific values			One forested acre in six is afforded some sort of protected status, a proportion similar to the national average. In addition to widespread conservation of these values on public lands, easements and trusts are increasingly being used on private lands. (See also Protected forest, item 3.)
34	Urban and community land			Eighty percent of the population in the North lives in urban areas, which comprise about 6 percent of the region's land area. The area of urban land increased by nearly 4 million acres or 0.9 percent from 1990 to 2000, and roughly 37 percent of the new urban area came from forests. (See also Population and urbanization, item 35.)
35	Population and urbanization, projected to 2050			Losses of forest land to urbanization are expected to continue. By 2050, Rhode Island (71 percent), New Jersey (64 percent), Massachusetts (61 percent), and Connecticut (61 percent) are expected to be more than half urban land.
36	Tree and impervious cover in urban and community areas			Northern urban or community areas have about 20 percent impervious surface and about 39 percent tree cover. By comparison, rural forest cover across the region is about 42 percent. As they expand, urban and community lands reduce the area of rural forest land but retain some tree cover.

^a Highly positive Positive Neutral Negative Highly negative



Literature Cited

- Association of Fish and Wildlife Agencies. 2011.** State wildlife action plans. Washington, DC: Association of Fish and Wildlife Agencies. http://www.stateforesters.org/issues_and_policy/forests_in_the_farm_bill. (24 January 2011).
- Barnes, M.C.; Todd, A.H.; Lilja, R.W.; Barten, P.K. 2009.** Forests, water and people: drinking water supply and forest lands in the Northeast and Midwest United States. NA-FR-01-08. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. 71 p.
- Butler, B.J.; Miles, P.D.; Hansen, M.H. 2010.** National Woodland Owner Survey table maker [Web application]. Version 1.0. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. <http://fiatools.fs.fed.us/NWOS/tablemaker.jsp>. (27 July 2011).
- Conservation Biology Institute. 2010.** Protected areas database PAD-US 1.1 CBI edition. Corvallis, OR: Conservation Biology Institute. <http://consbio.org/what-we-do/protected-areas-database-pad-version-4>. (14 November 2010).
- Dietzman, D.; Lajeunesse, K.; Wormstead, S. 2011.** Northern forest futures project: Scoping of issues in the forests of the Northeast and Midwest of the United States. Version 3.0. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 42 p.
- Fry, J.A.; Coan, M.J.; Homer, C.G.; Meyer, D.K.; Wickham, J.D. 2009.** Completion of the national land cover database (NLCD) 1992–2001 land cover change retrofit product. U.S. Geological Survey Open-File Rep. 2008–1379. Reston, VA: U.S. Department of Interior, Geological Survey. 18 p. <http://pubs.usgs.gov/of/2008/1379/>. (9 January 2011).
- Homer, C.; Huang, C.; Yang, L.; Wylie, B.; Coan, M. 2004.** Development of a 2001 national land-cover database for the United States. Photogrammetric Engineering and Remote Sensing. 70(7): 829-840. Data from multi-resolution land characteristics consortium. www.mrlc.gov. (14 August 2008).
- Howard, J.L. 2007.** U.S. timber production, trade, consumption, and price statistics 1965 to 2005. Res. Pap. FPL-RP-637. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 91 p.
- Malmsheimer, R.W.; Heffernan, P.; Brink, S. [et al.]. 2008.** Forest management solutions for mitigating climate change in the United States. Journal of Forestry. 106(3):119-171.
- Montréal Process Working Group. 2010.** The Montréal Process Criteria and Indicators. http://www.rinya.maff.go.jp/mpci/criteria_e.html. (5 July 2011).

Multi-Resolution Land Characteristics Consortium (MRLC). 2011. National land cover database. Sioux Falls, SD: U.S. Department of Interior, Geologic Survey, Earth Resources Observation and Science Center. www.mrlc.gov. (14 August 2008).

NatureServe. 2010. NatureServe explorer. <http://www.natureserve.org/explorer/>. Arlington, VA: NatureServe. (28 March 2011).

Protected Areas Center. 2010. Data basin: PAD-US 1.1 (CBI edition). <http://www.databasin.org/protected-center/features/PAD-US-CBI>. Corvallis, OR: Conservation Biology Institute. (12 November 2010).

Radeloff, V.C.; Hammer, R.B.; Stewart, S.I. [et al.]. 2005. The Wildland Urban Interface in the United States. *Ecological Applications*. 15: 799-805.

Shifley, S.R.; Aguilar, F.X.; Song, N.; Stewart, S.I.; Nowak, D.J.; Gormanson, D.D.; Moser, W.K.; Wormstead, S.; Greenfield, E.J. 2012. Forests of the Northern United States. Gen. Tech. Rep. NRS-90. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 202 p.

Smith, W.B.; Miles, P.D.; Perry, C.H.; Pugh, S.A. 2009. Forest resources of the United States, 2007. Gen. Tech. Rep. WO-78. Washington, DC: U.S. Department of Agriculture, Forest Service. 336 p.

U.S. Census Bureau. 2010. Population estimates. Washington, DC: U.S. Department of Commerce. <http://www.census.gov/popest/estimates.html>. (26 March 2011).

U.S. Department of Agriculture, Forest Service. 2011a. Forest health technology enterprise team: national insect and disease risk map/data. Washington, DC: U.S. Department of Agriculture, Forest Service. <http://www.fs.fed.us/foresthealth/technology/nidrm.shtml>. (28 January 2011).

U.S. Department of Agriculture, Forest Service. 2011b. National report on sustainable forests – 2010. FS-979. Washington, DC: U.S. Department of Agriculture, Forest Service. 212 p. <http://www.fs.fed.us/research/sustain/2010SustainabilityReport/>. (11 June 2011).

U.S. Department of Agriculture, Forest Service; Northeastern Area Association of State Foresters. 2011. 2010 Statewide forest resource assessments and strategies in the Northeast and Midwest: A regional summary. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry. 51 p. <http://www.forestationplans.org/regions/northeastern-region> (12 August 2011).

Van Deusen, P.; Heath, L.S. 2009. COLE web applications suite. NCASI and USDA Forest Service, Northern Research Station. Research Triangle Park, NC: National Council for Air and Stream Improvement; and Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. <http://www.ncasi2.org/COLE/> (28 March 2010).

Vogelmann, J.E.; Howard, S.M.; Yang, L. [et al.]. 2001. Completion of the 1990's national land cover data set for the conterminous United States. *Photogrammetric Engineering and Remote Sensing*. 67: 650-662.

World Commission on Environment and Development. 1987. Our common future. Oxford, UK: Oxford University Press. 400 p.





U.S. Department of Agriculture



U.S. Forest Service

General Technical Report

NRS-90 ES

2012