Forest Conditions and Trends in the Northern United States

5

THIS SECTION DESCRIBES current conditions and trends for the 20 Northern States by focusing on selected characteristics associated with forest sustainability. Its format is based upon a set of 64 indicators within 7 broad criteria that the United States and 11 other countries have adopted under the auspices of the Montréal Process Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests (Montréal Process Working Group 2010).

To these, we have added an eighth criterion focused on the urban and community forests in the northern United States.

The indicators are qualitative or quantitative variables intended to relay complex ecological information in a simple and useful manner (Kurtz et al. 2001). To be effective, these variables must be indicative of a larger ecological process, easy to measure, cost-effective, and repeatable (Burger and Kelting 1999). Indicators can identify trends, but they cannot fully explain the causes for observed changes or predict future conditions. Rather, indicator data must be evaluated in association with other monitoring data and verified by rigorous and targeted research to assess potential impacts on ecosystem function (O'Neill et al. 2005).

The Montréal Process was the framework for reporting forest conditions at the national scale in 2003 (USDA FS 2004) and 2010 (USDA FS 2011e). In a collaborative effort, the U.S. Forest Service and Northeastern Area Association of State Foresters collectively measure and monitor a subset of the indicators across the region and report findings in print (Carpenter 2007) and online (USDA FS 2010d). Individual State forestry agencies have used the Montréal Process criteria and indicator framework for forest resource assessments, as have organizations assessing local forest conditions at finer spatial scales (Baltimore County Maryland Department of Environmental Protection and Resource Management 2007). This chapter draws from these sources, from the Forest Service Forest Inventory and Analysis program (Miles et al. 2010, Smith 2009), and from numerous other sources to present an overview of current conditions and recent trends in the North.

Criteria and Indicators for Sustainable Forests

The United States and 11 other nations have agreed to follow a consistent set of guidelines for summarizing information that describes the characteristics of a nation's forests, including information considered important to understanding forest sustainability. These are often called the Montréal Process Criteria and Indicators because they originated at a meeting in Montréal (Montréal Process Working Group 2010). Each of the following seven criteria is described by a number of indicators (in parentheses). An eighth criterion was added for this assessment to reflect the importance of urban and community forests in the Northern United States.

1. Conservation of biological diversity (9)
2. Maintenance of productive capacity of forest ecosystems (5)
3. Maintenance of ecosystem health and vitality (2)
4. Conservation and maintenance of soil and water resources (5)
5. Maintenance of forest contribution to global carbon cycles (3)
6. Maintenance and enhancement of long-term multiple socioeconomic benefits to meet the needs of societies (20)
7. Legal, institutional, and economic framework for forest conservation and sustainable management (20)
8. Urban and community forests

Examples of individual indicators that are particularly relevant to northern forests include:

- Area and percent of forest by forest ecosystem type, successional stage, age class, and forest ownership or tenure
- Fragmentation of forests
- Number and status of native forest associated species at risk, as determined by legislation or scientific assessment
- Annual harvest of wood products by volume and as a percentage of net growth or sustained yield
- Area and percent of forest affected by abiotic agents (such as fires, storms, and land clearance) beyond reference conditions
- Proportion of forest management activities that meet best management practices, legislation, or other relevant efforts to protect soil resources
- Total forest ecosystem carbon pools and fluxes
- Value and volume of wood and wood products production, including primary and secondary processing
- Revenue from forest-based environmental services
- Exports as a share of wood and wood products production, and imports as a share of wood and wood products consumption
- Employment in the forest sector
- Methodologies to measure and integrate environmental and social costs and benefits into markets and public policies, and to reflect forest-related resource depletion or replenishment in national accounting systems
- New technologies and the capacity to assess the socioeconomic consequences associated with their introduction

Some indicators can be evaluated using readily available data sources, but others cannot. Findings for some indicators are easier to interpret than others. Nevertheless many nations, States, and even some counties choose to follow this framework for reporting forest sustainability information, making it a relevant way to understand forest conditions in context and across multiple spatial scales.

Although other formats could be used to present this information, the Montréal Process is well developed, widely used, and especially well suited to making comparisons with forest conditions elsewhere. In addition to the usual statistics for forest area, volume, utilization, and economic output, the broad criteria of the Montréal Process emphasize other important forest characteristics that typically receive less attention or that have a shorter monitoring history: biodiversity, forest fragmentation, forest soils, water quality and quantity, carbon cycling, social benefits, and institutional frameworks. Understanding the Montréal Process is not a precondition for interpreting or understanding this chapter. However, knowledge of the Montréal Process will be helpful for those who wish to contrast the conditions of northern forests with those of the entire United States or other participating nations. Ultimately the purpose of the criteria and indicators is to provide information relevant to understanding and interpreting forest sustainability.

The following eight subsections address the eight broad sustainability criteria identified for northern forests and include information about many of the individual indicators associated with each criterion. Montréal Process indicators that lack suitable data for northern forests are omitted.

Criterion 1:

CONSERVATION OF BIOLOGICAL DIVERSITY

Montréal Process Criterion 1 (Montréal Process Working Group 2010); Northern Area Forest Sustainability Indicators 1.1-1.5, 2.1-2.3, 3.1-3.5, 4.1–4.4, 15.3–15.6 (USDA FS 2010d)[1]

The importance of conserving biological diversity

Biological diversity, or biodiversity, is the variety of life. It encompasses the variability among living organisms and includes diversity within species, among species, and among ecosystems. High biodiversity enables a forest ecosystem to respond to external influences, absorb and recover from disturbances, and still maintain essential ecosystem processes such as regeneration, nutrient cycling, support of wildlife, and purification of air and water.

The Convention on Biological Diversity (2010) defines forest biological diversity as encompassing the multitude of plants, animals, and micro-organisms that inhabit forest areas and their associated genetic diversity. Both human activities and natural processes can reduce biological diversity by altering and fragmenting habitats, introducing invasive species, or reducing a species' population size or range. Sustaining biodiversity is among the top concerns commonly expressed about northern forests (Chapter 2).

[1] *This and similar information at the beginning of subsequent sections cross-reference information for Northern forests with the Montréal Process Criteria and Indicator system and with information in the Northern Area Forest Sustainability Indicators System.*

Although measuring biological diversity in forests is not simple, it is important because forests are a major source of biodiversity in the North and are relatively undisturbed compared to the agricultural or developed lands that dominate in some areas. Biodiversity is often reported at three scales: (1) diversity of ecosystems on the landscape; (2) species diversity including the total number of species and their relative frequency; and (3) genetic diversity, which is difficult to measure directly and often inferred from population size.

In general, forest ecosystems that have greater diversity are considered more resilient. Northern forests are long-lived and widespread so they are inevitably afflicted by catastrophic weather, wildfires, insects, diseases, invasive species, atmospheric pollution, and climate change. Forests with diversity at landscape, species, and genetic scales are more likely to remain fully functioning forest ecosystems over the long run.

Key Findings for Criterion 1

- 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 forests are 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.

Indicators of biodiversity for northern forests

Forest area

Forests cover 42 percent of the northern land base (Table 1), a greater percentage than the three other large regions of the country and far greater than the entire U.S. coverage of 33 percent (Fig. 1, Table 1, Appendix). Over the past century, forest cover in the North has increased by 28 percent, from 134 to 172 million acres (Fig. 2), mostly the result of natural succession after the abandonment of marginal farmlands that earlier replaced native forest. Simultaneously, as urban populations have increased, adjacent forests have been converted to nonforest land uses. From 1990 to 2000 the total area of urban land in the North increased by 4 million acres of which 1.5 million acres were forest (see Criterion 8).

Although most Northern States have seen a net increase in forest land over the past century, many have experienced periods of decrease as well as periods of increase over that time (Fig. 2). The increases in forest area for the North appear to be leveling off (Drummond and Loveland 2010); over the past 20 years about half the States increased in forest area and the other half decreased. Although total forest area is expected to remain relatively stable in the near term, forest locations will shift as some areas are cleared for development or agriculture, and others are returned to forest cover.

Most northern forest land (128 million acres, 74 percent) is privately owned (Fig. 7, Table 2). Families are the largest owner group, representing 4.7 million of the 5 million private owners. The other 300,000 private owners include forest products companies, corporations, trusts, nongovernmental organizations, and investment companies.

Most private ownerships are small; the average size is about 26 acres, and 3 million private owners have fewer than 10 acres of forest land. Conversely, the 10 percent of private owners with the most forest land collectively own more than half of all private forest acreage in the North (Butler 2008, Smith et al. 2009).

The other 44 million acres of northern forest land are publicly owned. Public forest land usually occurs in larger blocks and is managed for different purposes than private land. Compared to the U.S. average (44 percent), the North has relatively little public forest land (26 percent); the only region with less is the South (13 percent). Overall, the East trails far behind the Western States in public ownership of forests: 67 percent for the Pacific Coast and 75 percent for the Interior West. The amount of public forest land varies considerably among Northern States, ranging from 6 percent in Maine to 57 percent in Minnesota (Table 2).

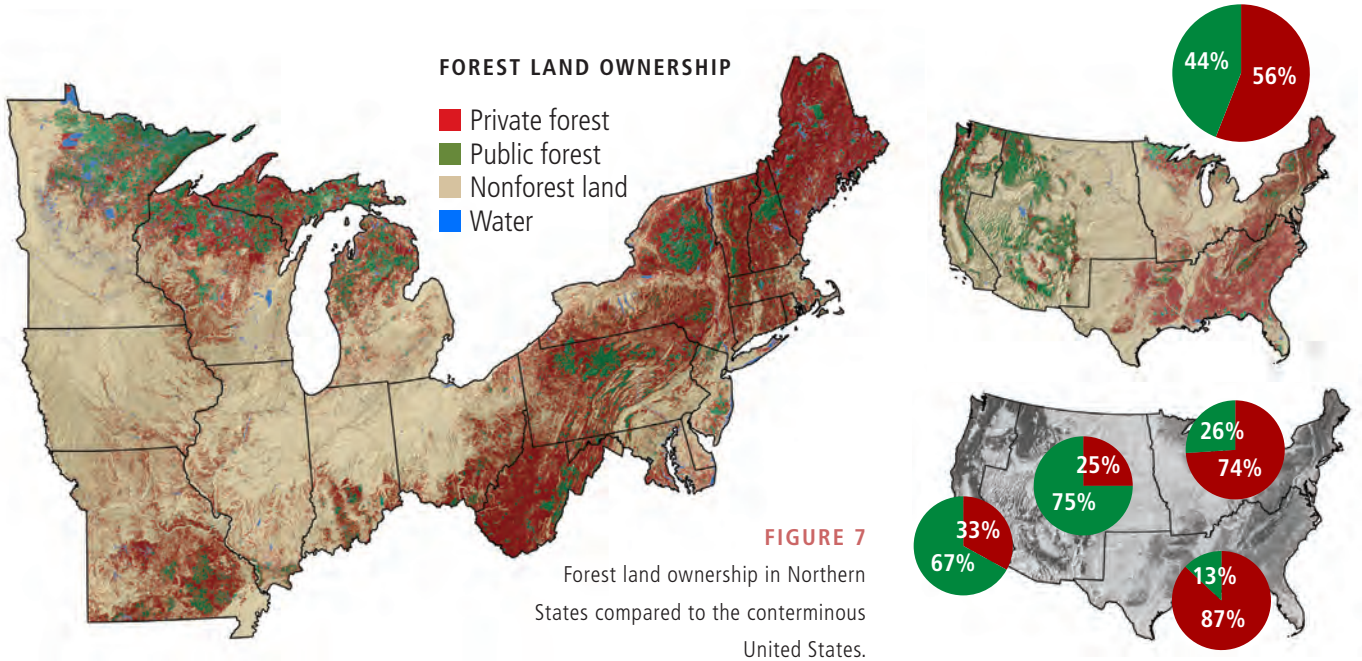


FIGURE 7
Forest land ownership in Northern States compared to the conterminous United States.

Table 2—Forest characteristics of the Northern States, 2007, ordered from most to least forest land (Smith et al. 2009). Note that data are standardized to an inventory year of 2007 and that newer State-specific data for some attributes are available from online sources (Miles 2010, USDA FS 2009b).

State	Land area	Forest land	Forest land	Reserved forest area	Reserved forest area	Public forest land	Private forest land	No. of private forest owners
	(1,000 acres)	(1,000 acres)	(percent of all land)	(1,000 acres)	(percent of forest land)	(percent of forest land)	(percent of forest land)	(1,000)
Michigan	36,275	19,545	54	325	1.7	38	62	498
New York	30,217	18,669	62	2,501	13.4	23	77	687
Maine	19,752	17,673	89	318	1.8	6	94	252
Pennsylvania	28,683	16,577	58	458	2.8	29	71	497
Minnesota	51,024	16,391	32	820	5.0	57	43	202
Wisconsin	34,791	16,275	47	107	0.7	32	68	362
Missouri	44,093	15,078	34	241	1.6	18	82	359
West Virginia	15,415	12,007	78	174	1.4	13	87	251
Ohio	26,207	7,894	30	228	2.9	12	88	345
New Hampshire	5,740	4,850	85	128	2.6	25	75	128
Indiana	22,980	4,656	20	123	2.6	16	84	225
Vermont	5,920	4,618	78	114	2.5	16	84	88
Illinois	35,608	4,525	13	162	3.6	18	82	184
Massachusetts	5,018	3,171	63	131	4.1	31	69	293
Iowa	35,842	2,879	8	15	0.5	11	89	150
Maryland	6,256	2,566	41	180	7.0	24	76	157
New Jersey	4,748	2,132	45	160	7.5	38	62	122
Connecticut	3,101	1,794	58	31	1.7	23	77	108
Delaware	1,251	383	31	0	0	8	92	55
Rhode Island	669	356	53	0	0	15	85	38
North total	413,586	172,039	42	6,216	3.6	26	74	5,002
U.S. total	2,263,870	751,228	33	74,664	9.9	44	56	11,322

Protected forests

Protected forest areas occur in a variety of forms including designated wilderness, parks, natural areas, conservation partnerships on private lands, and areas protected by nongovernmental organizations. Collectively protected areas comprise approximately 16 percent of northern forest land (see also Criterion 7). Protected forests can be categorized by their level of protection. Some have almost no human management intervention. Others allow active management to maintain biodiversity (using prescribed fire for example) but exclude timber harvesting. Other areas—such as national forests, State forests, and some private forests—may be actively managed for multiple resources with an emphasis on sustaining biodiversity.

Reserved forest land is a category of protected forest (such as State and Federal parks and wildernesses), mostly in public ownership, that has been permanently excluded from timber harvesting, either by law or by administrative order. Six million acres (3.6 percent) of all northern forest land is in reserved forests (Table 2), a relatively small amount compared to western forests (Fig. 8).

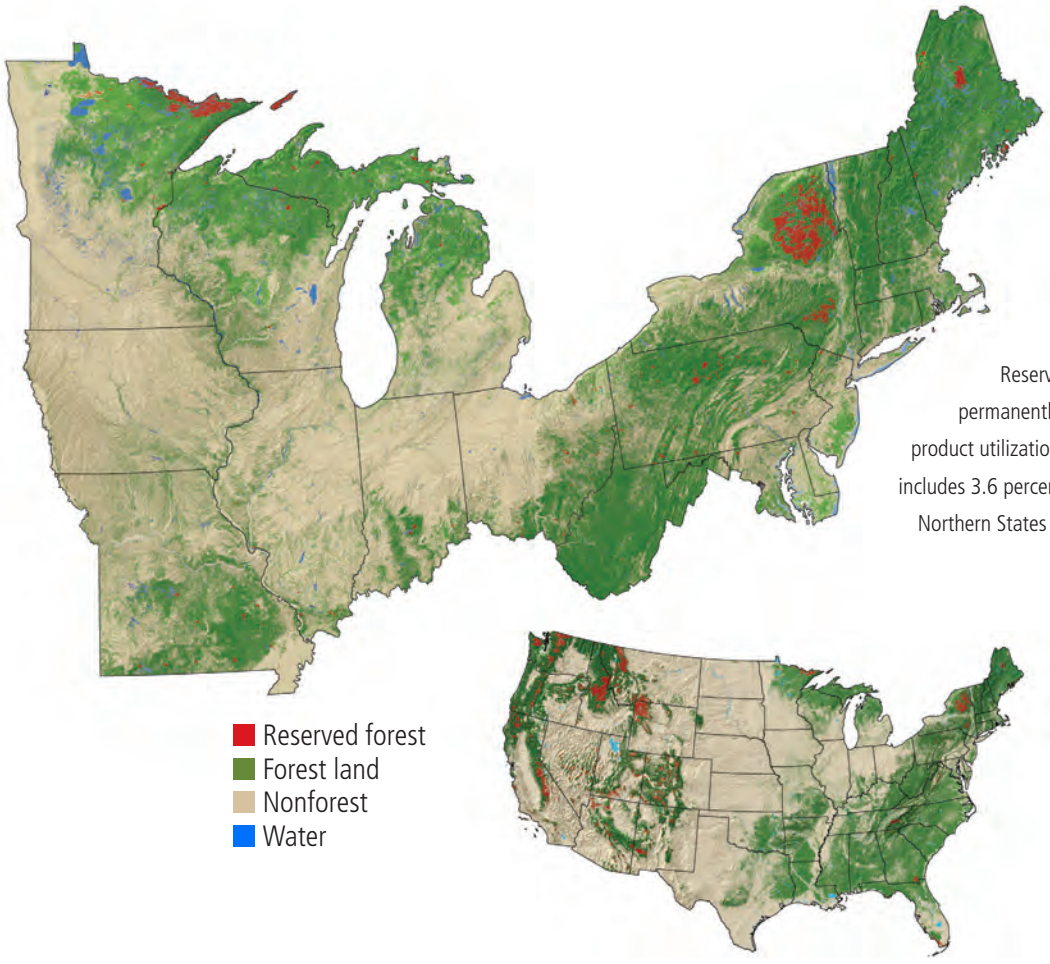


FIGURE 8

Reserved forest land (land is permanently removed from wood product utilization) in public ownership includes 3.6 percent of forest land in the Northern States and nearly 10 percent in the United States.

Forest land preservation agreements, trusts, and other voluntary land protection agreements have increased the area of protected private forest acreage in recent years. Developing a full inventory of private forests with conservation partnerships and other forms of protection is a work in progress. State and Federal conservation agreements on private forest land cover nearly 6 million acres of northern forests (3.5 percent of all forest land). Seventeen percent (28 million acres) of private northern forest land is voluntarily enrolled in State tax reduction programs that establish forest management guidelines and land use restrictions. Approximately 24 million acres of public and private forest land (14 percent of northern forest land) are enrolled in the Forest Stewardship Council third-party forest certification program. These categories of protection are not mutually exclusive; rather they represent a range of alternative methods to maintain forest cover and sustain forest values (USDA FS 2010e, 2010f).

Forest cover types and age classes

Although nine broad forest type groups—each named for its dominant tree cover—can be found in northern landscapes (Table 3, Fig. 9), the most common are the oak-hickory and the maple-beech-birch forest-type groups occupying 35 percent and 29 percent of the forest area, respectively.

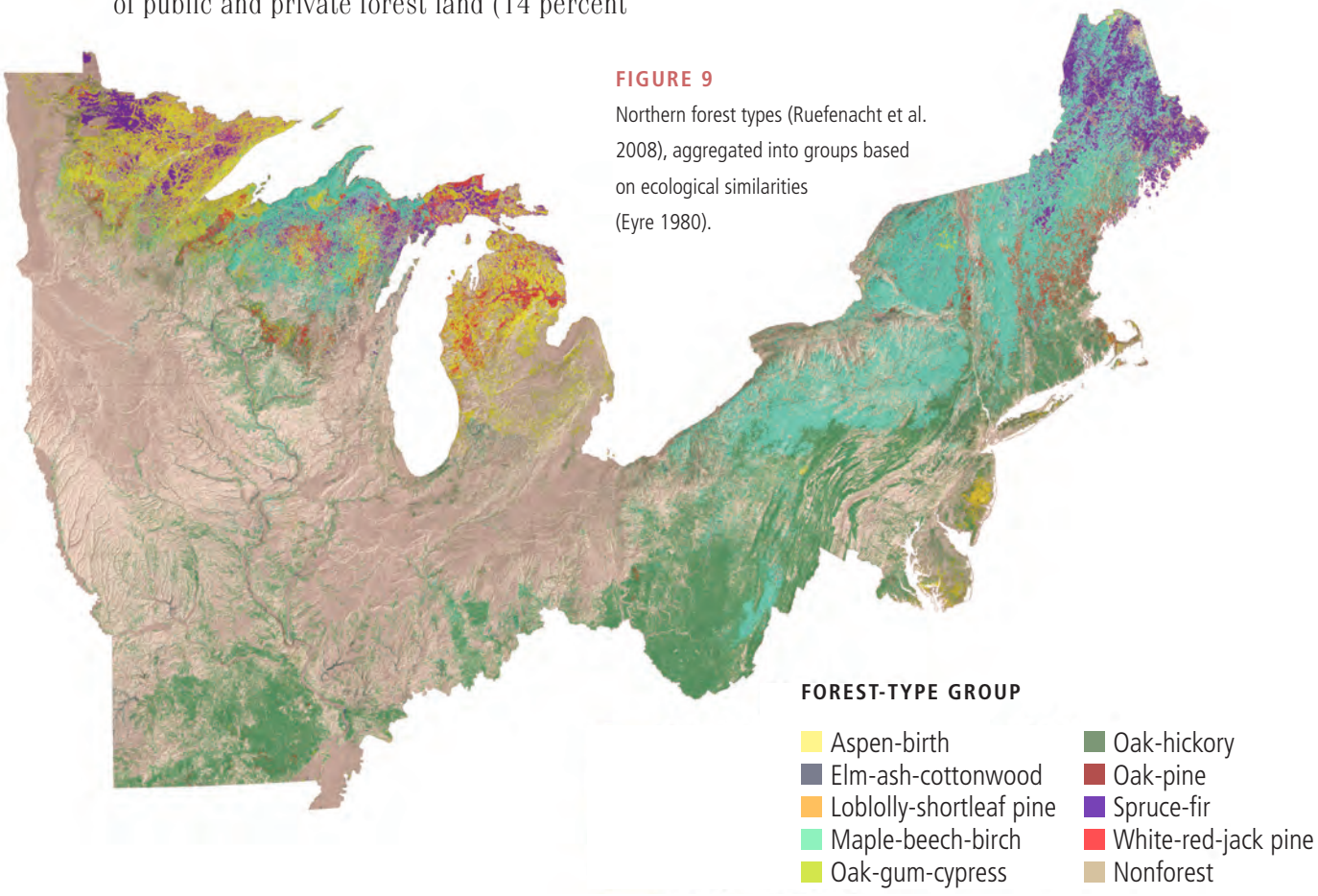


FIGURE 9

Northern forest types (Ruefenacht et al. 2008), aggregated into groups based on ecological similarities (Eyre 1980).

Table 3—Forest area for the Northern States by forest-type group, 2007, with States ordered from most to least timberland area and forest-type groups ordered from most to least proportion of area for the region (Miles 2010, Smith et al. 2009). Note that data have been standardized to an inventory year of 2007 and that newer State-specific data for some attributes are available from online sources (Miles 2010).

State and region	Forest land	Proportion of all Northern forest land	Oak hickory	Maple beech birch	Aspen birch	Spruce fir	Elm ash cotton-wood	White red jack pine	Oak pine	Loblolly short-leaf pine	Oak gum cypress	Non-stocked	Other types
	(1,000 acres)	(percent)	(percent of forest-type group area by state or region)										
Michigan	19,545	11.4	16	32	16	13	7	10	3	0	0	1	1
New York	18,669	10.9	21	54	4	3	4	7	3	0	0	1	2
Maine	17,673	10.3	2	40	13	33	2	8	2	0	0	0	0
Pennsylvania	16,577	9.6	51	39	2	0	2	3	2	1	0	1	1
Minnesota	16,391	9.5	9	10	40	23	9	6	2	0	0	2	0
Wisconsin	16,275	9.5	23	26	20	9	9	9	4	0	0	1	0
Missouri	15,078	8.8	80	2	0	0	7	0	7	1	0	0	3
West Virginia	12,007	7.0	67	26	0	0	2	1	3	1	0	0	0
Ohio	7,894	4.6	62	23	1	0	8	1	2	1	0	1	1
New Hampshire	4,850	2.8	8	54	7	8	2	14	7	0	0	0	0
Indiana	4,656	2.7	62	19	0	0	11	1	3	1	1	0	1
Vermont	4,618	2.7	4	68	6	7	2	11	2	0	0	0	1
Illinois	4,525	2.6	67	5	0	0	22	1	1	1	1	1	1
Massachusetts	3,171	1.8	30	27	1	0	6	15	14	2	2	1	0
Iowa	2,879	1.7	57	11	0	0	24	0	3	0	0	3	1
Maryland	2,566	1.5	64	5	0	0	2	0	10	11	4	1	1
New Jersey	2,132	1.2	46	11	0	0	2	0	8	22	8	1	2
Connecticut	1,794	1.0	71	11	0	0	6	6	3	0	2	1	0
Delaware	383	0.2	72	0	0	0	4	0	6	10	7	1	0
Rhode Island	356	0.2	56	16	1	0	5	6	8	4	3	1	1
North total	172,039	100.0	35	29	10	9	6	6	3	1	0	1	1

Northern forests are aging. Most of the primary (old-growth) forests were cut more than a century ago, and cutover areas that were not converted to agricultural or residential use typically regenerated naturally to second-growth forest. For about the last 40 years disturbances that regenerate new forests (such as timber harvesting or intense wildfires) have been relatively infrequent. Thus, about 70 percent of northern forest land is between 40 and 100 years old, creating a distinctly bell-shaped forest age distribution (Fig. 10). Young forests and very old forests are relatively rare, so there is relatively little habitat for species that depend on these forest age classes. This reduces forest diversity compared to landscapes that have a more balanced age structure with a similar proportion of forest area in each age class. If current rates of forest disturbance and regeneration continue, the average forest age will increase over time.

Fragmentation and parcelization

Forest fragmentation occurs when patches of nonforest land are created within a forest, patches of forest land are reduced in area, and/or forested corridors connecting forest patches are broken. This reduces forest area and increases the amount of edge habitat between forest and nonforest land. As fragmentation continues, forest patches can become disconnected from one another within a mosaic of other land uses. Fragmentation alters habitat suitability for forest-dwelling species.

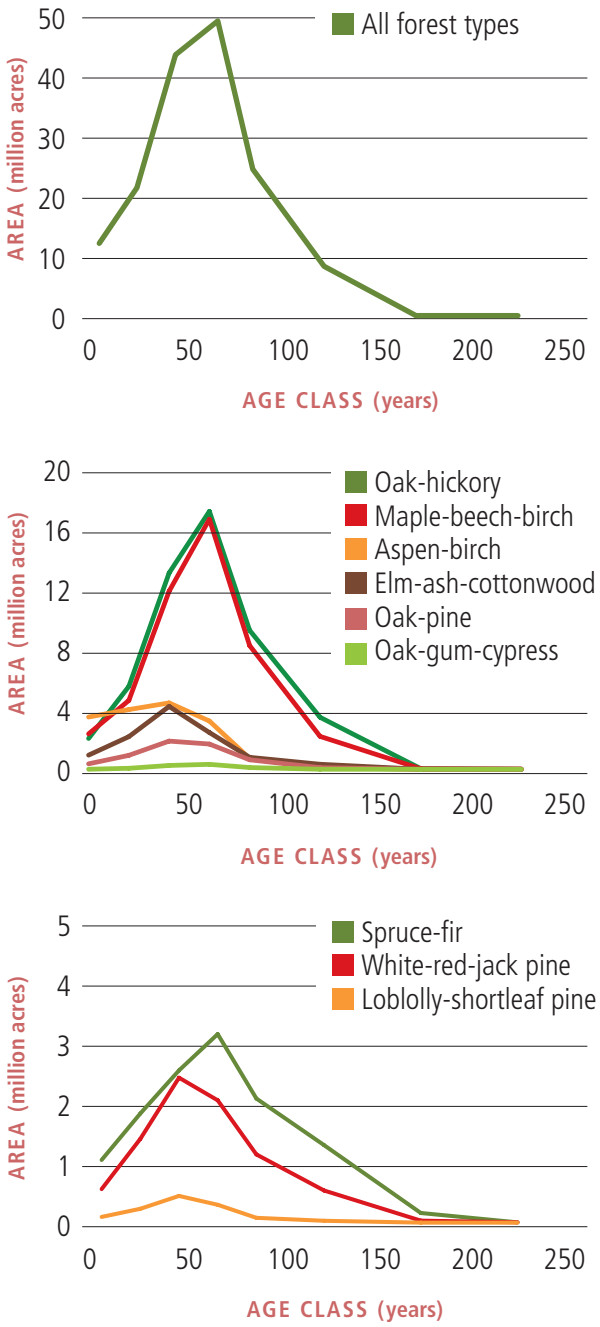


FIGURE 10

Forest age class distribution by forest-type group, Northern States, 2007 (Smith et al. 2009).

Fragmentation can reduce connectivity among forest patches, potentially restricting species movement and limiting genetic diversity within isolated plant and animal populations. Edge habitats favor different species than do the increasingly rare interior habitats of northern forests. Generally, retaining large forest patches is desirable because (1) large contiguous forest patches are relatively rare compared to small forest patches, and (2) over time human and natural disturbances tend to increase fragmentation, reduce forest patch size, and reduce the amount of forest interior habitat.

The degree of forest fragmentation cannot be distilled into a single number, because fragmentation statistics are affected by the spatial scale of analysis. For example, a relevant patch size opening in forest cover could be one-tenth of an acre, 1 acre, or 10 acres, depending on which forest-associated species are of interest. Likewise different forest-associated species (e.g., salamanders versus migrant birds versus humans) differ in the spatial scales at which they perceive and respond to fragmentation effects. In addition to patch size, the total area of forest land, density of forest land within a particular locale, the shape and pattern of forest patches, and rates of conversion of land to or from forest all play a role in fragmentation computations. Figures 7, 11, and 12 illustrate forest fragmentation in different ways and/or at different spatial scales.

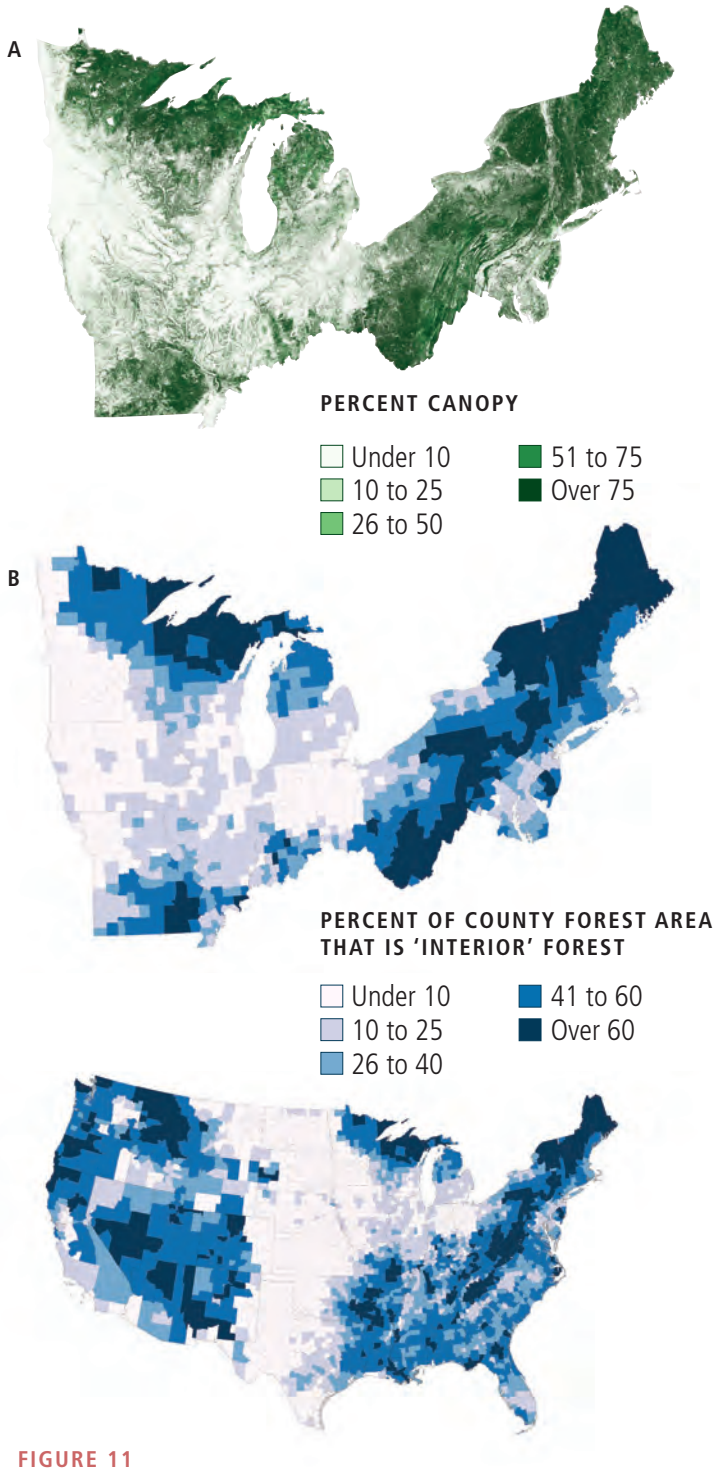
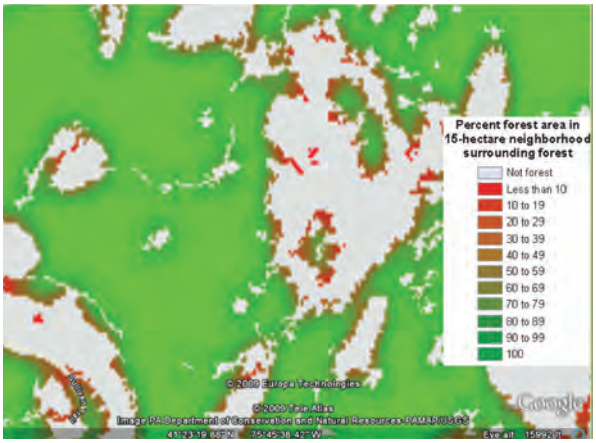


FIGURE 11

Forest area and fragmentation showing (A) forest density for the Northern States (Homer et al. 2004), and (B) fragmentation for the Northern States and the conterminous United States, with percent of interior forest measured as the percent of 40-acre blocks for each county that have at least 90 percent forest cover (source: Kurt Riitters, U.S. Forest Service; USDA FS 2011e).

A

B



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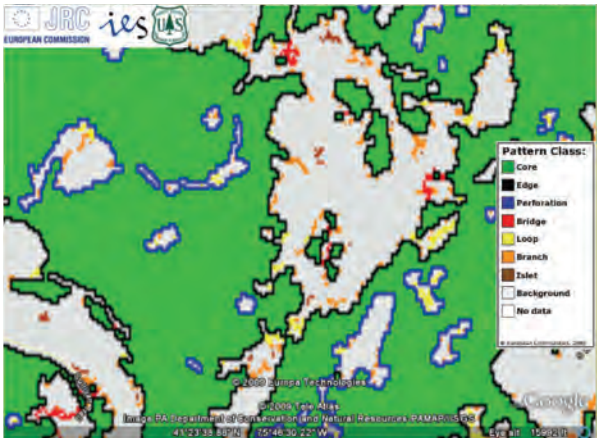

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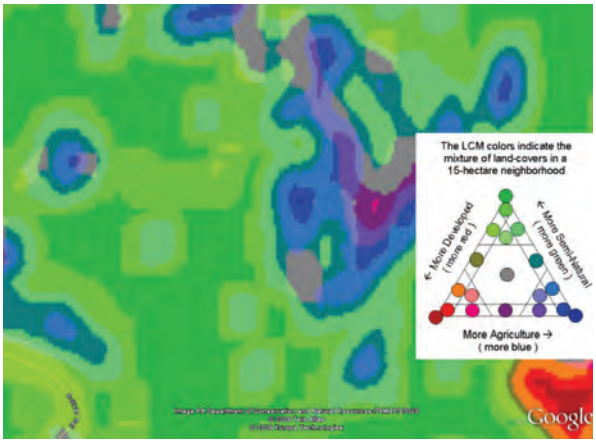


FIGURE 12

Fine scale fragmentation images from a landscape west of Scranton, PA: (A) aerial photograph of the area, (B) forest density, (C) forest fragmentation, and (D) land cover; these map layers are available for the conterminous United States and can be viewed or analyzed at large and small spatial scales [sources: Pennsylvania Department of Conservation and Natural Resources-PAMAP/USGS with additional processing by Europa Technologies©2009 and Tele Atlas©2009; Kurt Riitters; Multi-resolution Land Characteristics Consortium 2011; USGS 2010; MRLC 2011; European Commission Joint Research Centre Institute for Environment and Sustainability 2011; image processing by Peter Vogt, Institute for Environment and Sustainability; image processing by Kurt Riitters, U.S. Forest Service, using methodology by Pierre Soille, Institute for Environment and Sustainability; layer production by Kurt Riitters using methodologies of Wickham and Norton (1994) and Riitters et al. (2008)].

Parcelization occurs when forest ownerships are divided into smaller tracts. The number of private forest owners in the North increased to 5 million in 2006 from 4 million in 1993, and the average ownership size decreased from 33 to 26 acres (Fig. 13). Owners of small tracts may have different objectives and employ different management practices than those who own large tracts (Butler 2008, Gobster and Rickenbach 2004). Parcelization does not necessarily result in physical separation of forested areas, but it often results in disparate owner objectives and management practices among adjacent ownerships. This can be a barrier to building the spatial continuity in management practices needed to address broad, landscape-scale issues.

FIGURE 13

Number of private forest owners in the North by size of forest ownership, 1993 and 2006 (Birch 1996, Butler 2008).

Number and status of native forest-associated species

The number of forest-associated species is an important indicator of forest biodiversity, as is the proportion of those species that may face extinction. Natural variation in forest ecosystems across the United States creates differences in the number of forest-associated species among regions (Fig. 14). Also, the amount of available information varies from one species group to the next—much is known about the number and status of forest associated birds, mammals, and vascular plants compared insects, fungi, and microorganisms.

Northern forests support 780 known animal species (USDA FS 2010f): 85 percent have populations that are apparently secure, 13 percent are at some level of risk of future extinction, 0.8 percent are presumed extinct, and 1.2 percent are classified as "unknown status" (Fig. 15). For individual States, the proportion of species that are at risk ranges from 3 to 9 percent, and less than 1 percent of species are classified as extinct. With more research, the number of known forest-associated species will increase and the proportion of extinct or at-risk species could increase or decrease although the likelihood of extinctions appears to be smaller than the likelihood of discovering additional forest-associated species in taxonomic groups such as insects or fungi.

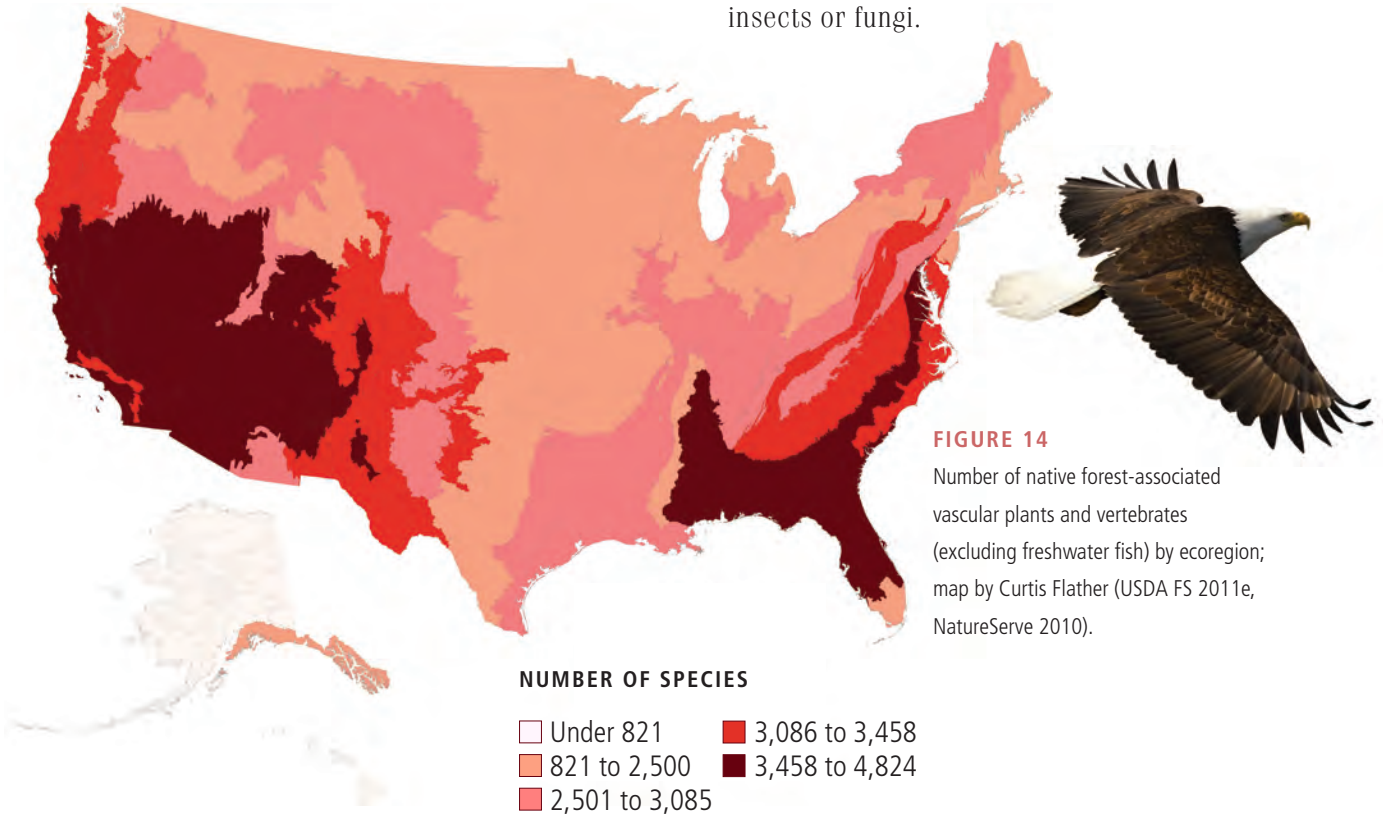


FIGURE 14
Number of native forest-associated vascular plants and vertebrates (excluding freshwater fish) by ecoregion; map by Curtis Flather (USDA FS 2011e, NatureServe 2010).

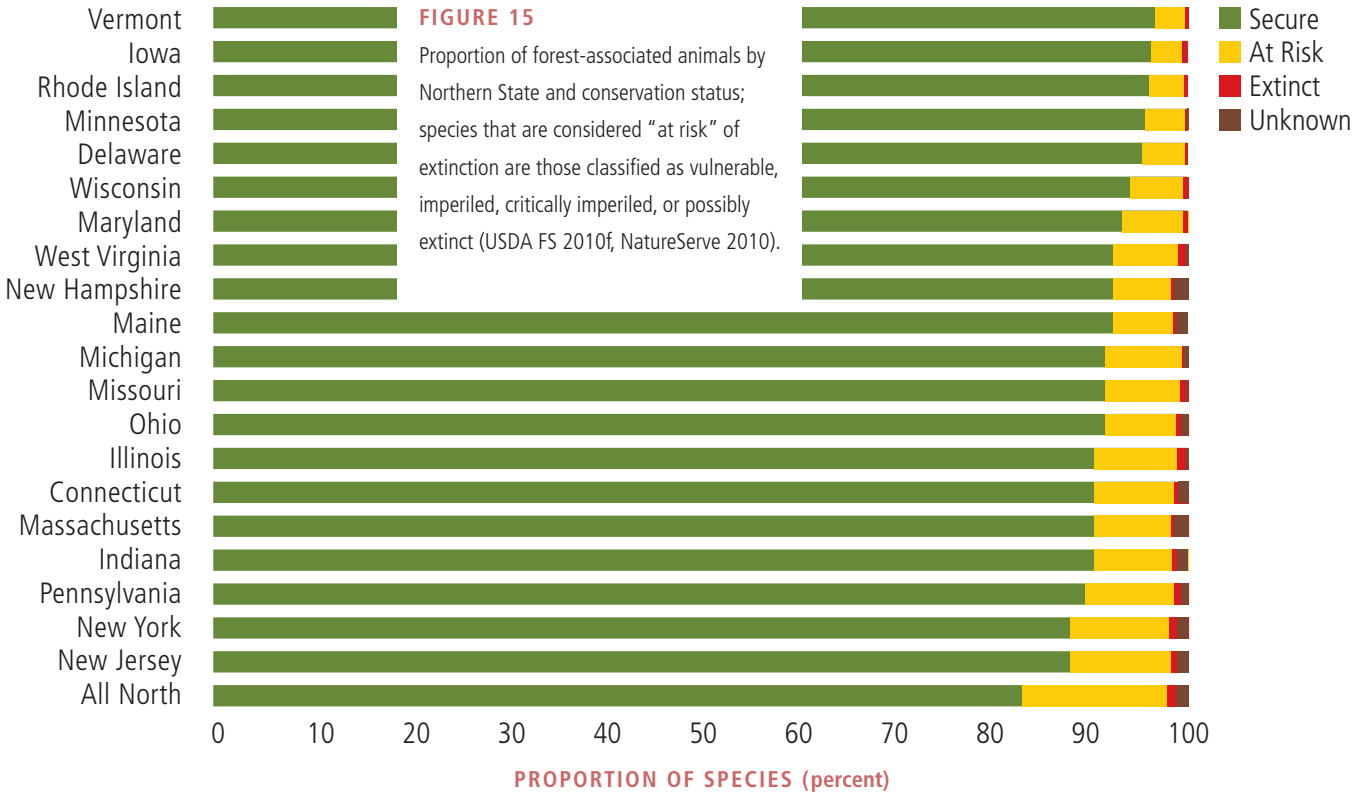


FIGURE 15

Proportion of forest-associated animals by Northern State and conservation status; species that are considered "at risk" of extinction are those classified as vulnerable, imperiled, critically imperiled, or possibly extinct (USDA FS 2010f, NatureServe 2010).

Species that are considered "at risk" are classified as vulnerable, imperiled, critically imperiled, or possibly extinct (NatureServe 2010). However, species that are not globally extinct or even at risk may still lose ground at a more local scale. Reductions in species' ranges are one way to quantify this effect. Compared with the rest of the Nation, Northern States have large numbers of extirpated (eliminated) species (Fig. 16).

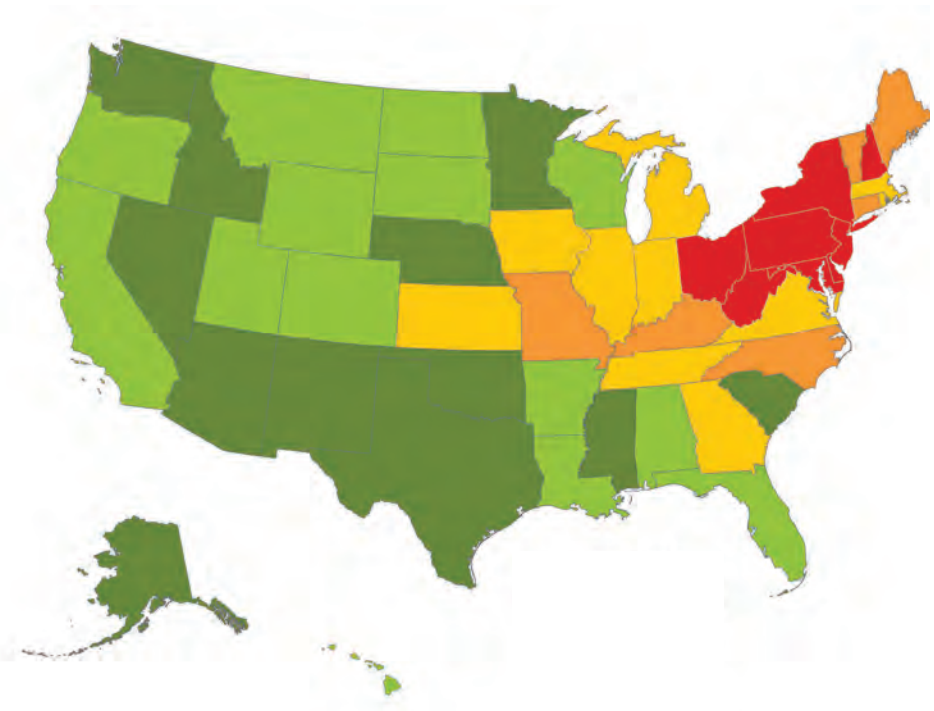


FIGURE 16

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 2011e, NatureServe 2010.

Criterion 2:

MAINTENANCE OF PRODUCTIVE CAPACITY OF FOREST ECOSYSTEMS

Montréal Process Criterion 2 (Montréal Process Working Group 2010); Northern Area Forest Sustainability Indicators 5.1, 6.1, 6.2 (USDA FS 2010d)

The importance of the productive capacity of forest ecosystems

People rely on forests, directly and indirectly, for a wide range of goods and services. Measures of forest productive capacity are indicators of the ability of forests to sustainably supply goods and services over time. An ongoing emphasis on maintaining productive capacity of forests can help ensure that utilization of forest resources does not impair long term forest productivity, even though the goods and services expected from forests may change over time due to social, economic, or technological trends.

Changes in the productive capacity of forests can arise from natural causes such as forest aging and species succession or from disturbances by weather, insects, diseases, wildfires, or invasive plants. Human interventions such as forest management and land use changes also affect the productive capacity of forests. Changes in productive capacity may signal the need or the opportunity to modify policies, management practices, or products to ensure a sustainable flow of desired goods and services.

This criterion is focused primarily on the capacity to produce wood products. However, information on harvesting nontimber forest products is reported to the extent that it is available (see also Criterion 6)

Indicators of the productive capacity of northern forests

Forest land and timberland

Timberland is the subset of forest land that is suitable for wood production. Timberland excludes forest in parks, wilderness, and other protected areas where harvesting is prohibited by policy or legislation. It also excludes forest areas unsuitable for commercial wood production because they are unproductive or physically

Key Findings for Criterion 2

- The North has 172 million acres of forest land of which 95 percent is suitable for timber production.
- The region's timberland is 77 percent privately owned, 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.
- 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 4—Timberland area and proportion by owner group for the Northern States, 2007, sorted from most to least forest land. Note that data have been standardized to an inventory year of 2007 and that newer State-specific data for some attributes are available from online sources (Miles 2010, Smith et al. 2009, USDA FS 2009b).

State and region	Forest land	Timberland	Timberland proportion of forest land	Private ownership	Public ownership	National Forest ownership[a]
	(1,000 acres)	(1,000 acres)	(percent)	(percent of timberland)	(percent of timberland)	(percent of timberland)
Michigan	19,545	19,023	97	63	37	13
New York	18,669	16,015	86	89	11	0
Maine	17,673	17,163	97	96	4	0
Pennsylvania	16,577	16,019	97	73	27	3
Minnesota	16,391	15,112	92	46	54	12
Wisconsin	16,275	16,042	99	69	31	9
Missouri	15,078	14,674	97	83	17	10
West Virginia	12,007	11,797	98	88	12	8
Ohio	7,894	7,645	97	91	9	3
New Hampshire	4,850	4,674	96	77	23	13
Indiana	4,656	4,533	97	86	14	4
Vermont	4,618	4,482	97	86	14	6
Illinois	4,525	4,363	96	85	15	6
Massachusetts	3,171	2,946	93	72	28	0
Iowa	2,879	2,824	98	89	11	0
Maryland	2,566	2,372	92	82	18	0
New Jersey	2,132	1,877	88	69	31	0
Connecticut	1,794	1,732	97	77	23	0
Delaware	383	376	98	93	7	0
Rhode Island	356	351	99	85	15	0
North total	172,039	164,018	95	77	23	6
U.S. total	751,228	514,213	68	69	31	19

[a]*National forest timberland is a subset of public timberland.*

inaccessible. Of the 172 million acres of northern forest land, 95 percent (164 million acres) is classified as timberland, far larger than the U.S. average of 68 percent (Table 4). Most timberland in the North is physically accessible and productive with relatively few tracts devoted to parks, wilderness, or other areas where harvesting is prohibited.

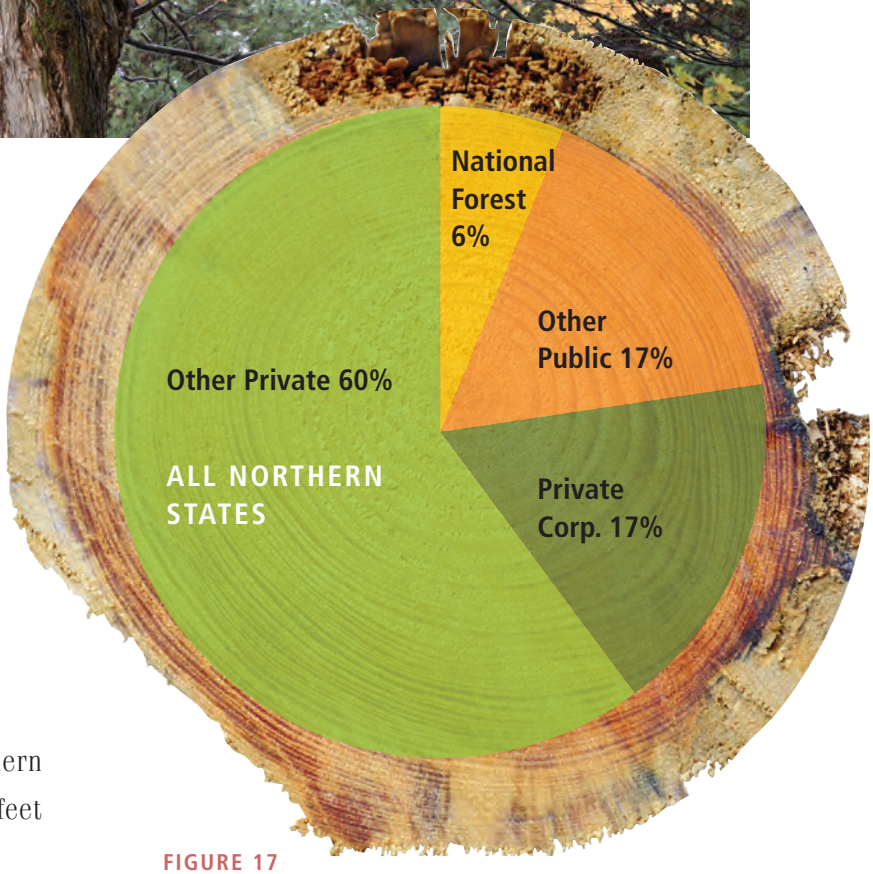


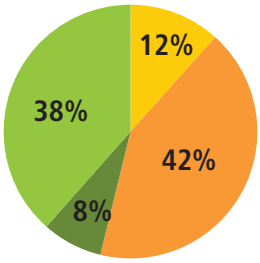
FIGURE 17

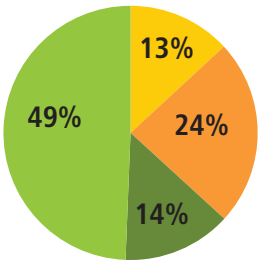
Proportion of timber land by owner group for all Northern States (this page) and by individual states (opposite page) ordered from lowest to highest proportion of all private timberland (Smith et al. 2009). Colors indicate the same owner category throughout all charts.

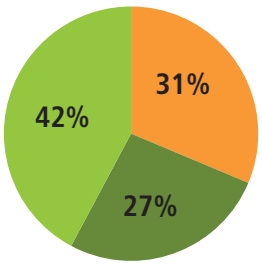
Overall, 77 percent of northern timberland is privately owned (Table 4), ranging from a low of 46 percent for Minnesota to a high of 96 percent for Maine (Fig. 17). Most private forest ownerships are small (Fig. 13), and most private owners do not consider wood production as their primary objective (Butler 2008).

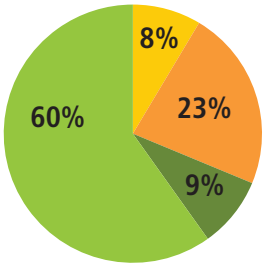
Wood volume

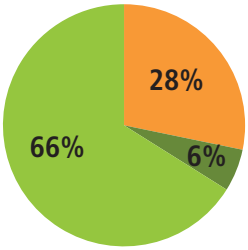
The volume of standing wood on northern timberland exceeds 268 billion cubic feet (Table 5). Approximately 92 percent (248 billion cubic feet) of that total volume is classified as growing stock—comprised of species and tree characteristics (form, size, and number of defects) that are acceptable for commercial wood products. Growing stock volume in the North averages 1,500 cubic feet per acre compared to the U.S. average of 1,800 cubic feet. Among Northern States, growing-stock volume ranges from a low of 988 cubic feet per acre in Minnesota to slightly more than 2,200 cubic feet in Massachusetts.

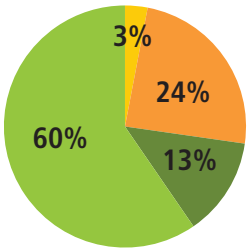

Minnesota
12%
38%
42%
8%

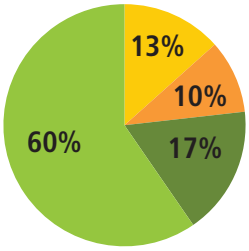

Michigan
13%
49%
24%
14%

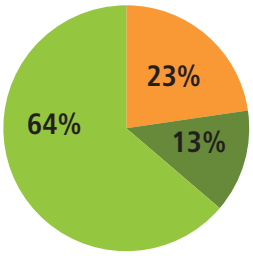

New Jersey
31%
42%
27%

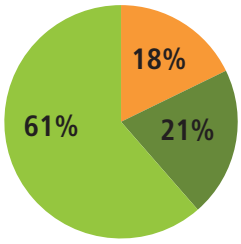

Wisconsin
8%
23%
60%
9%

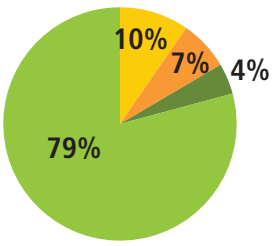

Massachusetts
28%
66%
6%

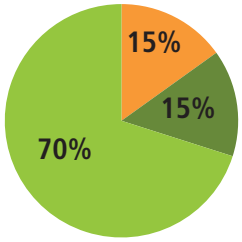

Pennsylvania
3%
24%
60%
13%

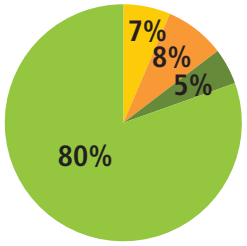

New Hampshire
13%
10%
60%
17%

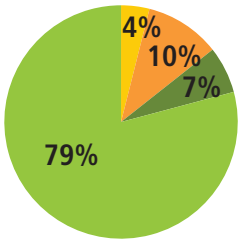

Connecticut
23%
64%
13%


Maryland
18%
61%
21%


Missouri
10%
7%
4%
79%


Rhode Island
15%
15%
70%


Illinois
7%
8%
5%
80%


Indiana
4%
10%
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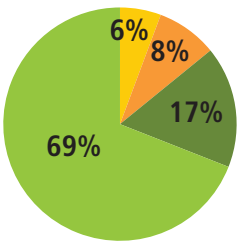
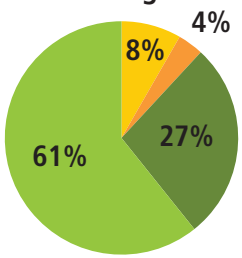

Vermont
6%
8%
17%
69%


West Virginia
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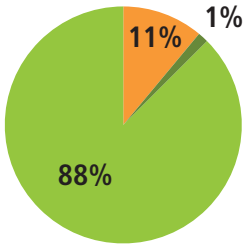
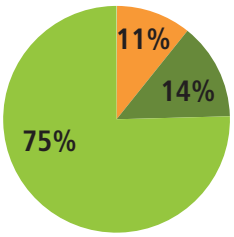
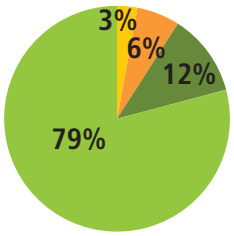
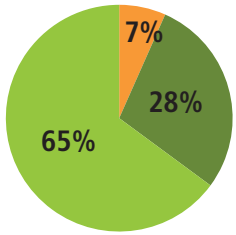
8%
27%
61%


Iowa
1%
11%
88%


New York
11%
14%
75%


Ohio
3%
6%
12%
79%


Delaware
7%
28%
65%

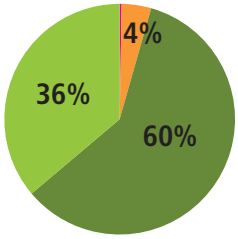

Maine
4%
36%
60%

Table 5—Area of timberland and timber volume (2007) and growth and removals of growing stock (2007 or 2008) from timberland in the Northern States ordered from the largest to smallest ratio of growing stock growth to removals—a relative indicator of utilization pressure (Miles 2010, Smith et al. 2009).

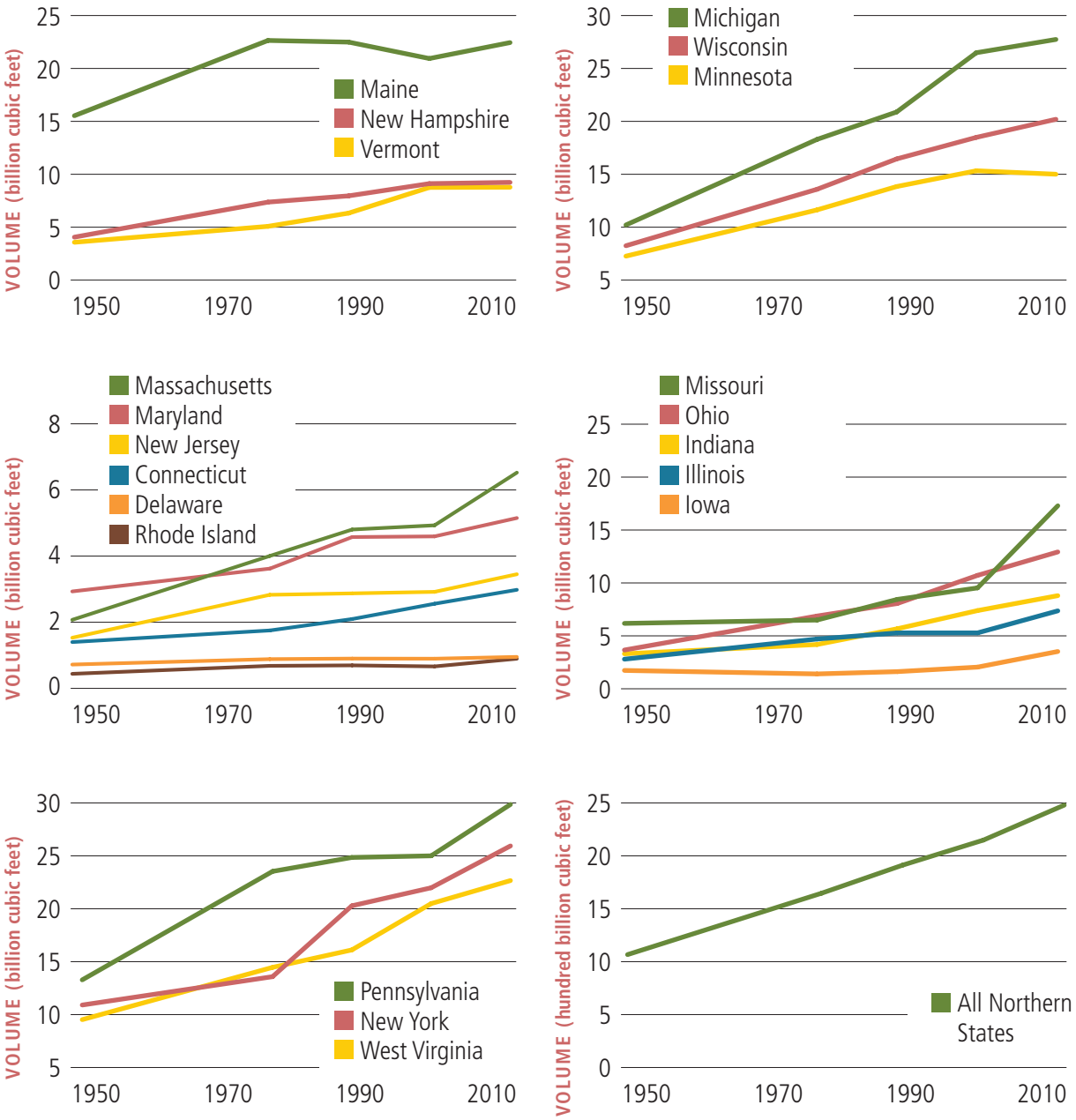
State and Region	Total timber-land area	Total volume	Cull or sound dead	Total growing-stock timber volume		Annual growth of growing stock		Annual removals of growing stock	Growth to removals ratio
	(1,000 acres)	(million cubic feet)	Proportion of total volume (percent)	(million cubic feet)	(cubic feet per acre)	(million cubic feet)	(percent increase)	(million cubic feet)	
Delaware	376	737	6	695	1,851	31	4.5	7	4.5
Rhode Island	351	663	4	637	1,814	19	3.0	4	4.4
Illinois	4,363	7,642	10	6,875	1,576	231	3.4	58	4.0
Indiana	4,533	9,098	9	8,281	1,827	318	3.8	80	4.0
New Jersey	1,877	2,968	5	2,819	1,503	95	3.4	29	3.3
Missouri	14,674	18,886	12	16,596	1,131	518	3.1	175	3.0
Maryland	2,372	5,254	3	5,092	2,147	178	3.5	67	2.6
Iowa	2,824	4,046	23	3,114	1,103	105	3.4	46	2.3
Massachusetts	2,946	6,978	6	6,530	2,216	144	2.2	62	2.3
Connecticut	1,732	3,501	5	3,312	1,913	89	2.7	41	2.2
Ohio	7,645	13,311	7	12,324	1,612	410	3.3	189	2.2
Michigan	19,023	30,418	8	28,029	1,473	703	2.5	339	2.1
New York	16,015	27,761	7	25,862	1,615	600	2.3	288	2.1
West Virginia	11,797	23,539	4	22,524	1,909	611	2.7	323	1.9
Pennsylvania	16,019	31,265	4	29,859	1,864	743	2.5	414	1.8
Wisconsin	16,042	22,268	9	20,271	1,264	598	3.0	327	1.8
Vermont	4,482	9,493	8	8,696	1,940	180	2.1	109	1.7
Minnesota	15,113	16,657	10	14,931	988	417	2.8	294	1.4
New Hampshire	4,674	9,880	7	9,156	1,959	164	1.8	150	1.1
Maine	17,163	23,935	6	22,402	1,305	573	2.6	562	1.0
North total	164,018	268,303	8	248,005	1,512	6,726	2.7	3,564	1.9
U.S. total	514,213	1,013,407	8	932,089	1,813	26,744	2.6	15,533	1.7

From 1953 to 2007 the volume of growing stock on timberland in the North more than doubled from 104 to 248 billion cubic feet (Fig. 18).

FIGURE 18

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

All 20 states in the region showed substantial increases in volume over this period. Volume in Maine increased by 40 percent, the least proportion of any state; Rhode Island increased by 400 percent, and most states more than doubled standing volume (see Appendix Table A8).



The spatial distribution of total wood volume by county (Fig. 19A) mirrors the spatial distribution of forest cover (Fig. 1). However, wood volume per acre of timberland (Fig. 19B) gives a different perspective of the region's timber resources by emphasizing counties that have high mean volume per acre of timberland, regardless of how many total timberland acres are in the county. Forests that are mature, healthy, and growing on productive sites have relatively high volume per acre.

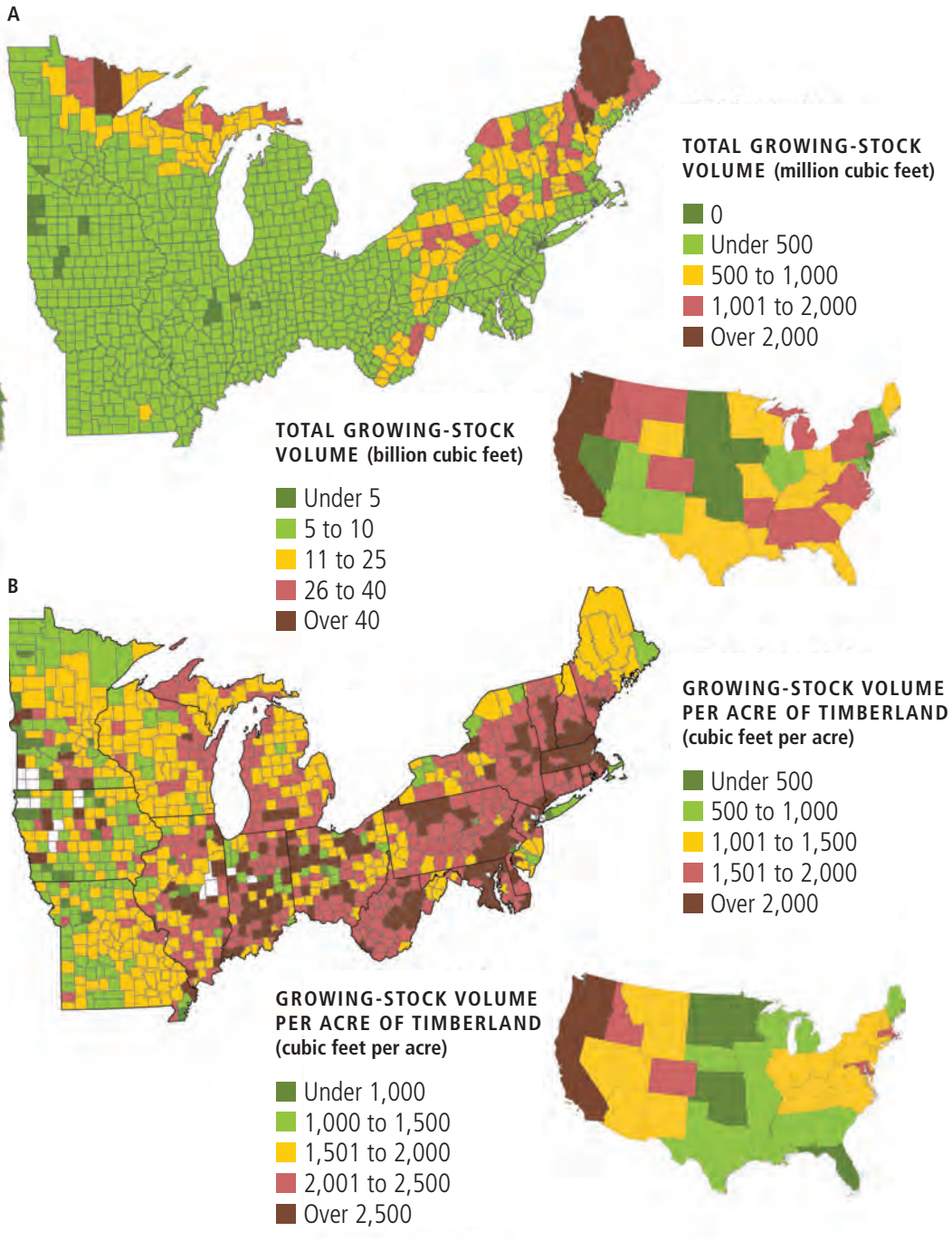


FIGURE 19

Spatial distribution of growing-stock volume in northern forests: (A) total growing-stock volume on timberland, showing where wood is concentrated and emphasizing large counties or large States with large amounts of wood; and (B) average growing-stock volume per acre of timberland, emphasizing counties and States with a large volume of wood per acre of timberland, regardless of total timberland acreage (Miles 2010).

Wood growth and removals

The annual volume growth rate of growing stock trees on northern timberland is 41 cubic feet per acre, well below the U.S. average of 52 cubic feet. Nevertheless, the annual growth of wood (growing stock) in the North exceeds removals by about 3.2 billion cubic feet (Table 5). The long-term trend of annual growth in excess of removals is the cause of the substantial volume increases in northern forest since the 1950s (Fig. 18).

The ratio of annual growth to removals is an indicator of the intensity of wood utilization. Removals estimates include wood removed during silvicultural operations as well as land clearing, with total removals including trees that were cut but unused as well as those used in products. A growth-to-removals ratio of 1.0 would indicate that wood is being removed as fast as it is growing. A ratio of less than 1.0 would indicate levels of harvesting and/or land conversion that are unsustainable over the long term because mean annual removals exceed mean annual growth. Across the North the current ratio of growth to removals is 1.9—each year growth is 1.9 times greater than removals (Table 5)—compared to a U.S. ratio of 1.7. Most Northern States have growth-to-removal ratios higher than 2; ratios are higher than 3 for Delaware, Rhode Island, Illinois, Indiana, and New Jersey. In States where management intensity and product utilization are relatively high—Maine, New Hampshire, and Minnesota—growth-to-removal ratios are lower than 1.5. Compared to Maine and Minnesota, New Hampshire has experience more conversion of forest land to urban land (see Criterion 8: Urban and Community Forests).

Planted forests

Under the proper conditions, forest plantations can grow more wood per acre over a given period than naturally regenerated forests. Attention to site and species selection, planting stock quality, competition control, fertilization, thinning, and efficient utilization often contribute to high productivity per acre from planted forests. Although plantations usually have lower species diversity than native forests, they provide increased productivity per acre that can (at least theoretically) offset timber harvesting elsewhere. And when converting sites to forest from agricultural, mining, or other land uses, planting trees is often faster than natural succession for establishing a new, closed canopy forest.

Only 3.5 percent (6 million acres) of northern forests are plantations, compared to 21 percent in the South and 8 percent (63 million acres) for the entire United States. From 1993 to 2003, planting averaged about 142,000 acres per year in the North, equivalent to 6 percent of the total planted area per year in the United States (Smith et al. 2009).

Criterion 3:

MAINTENANCE OF FOREST ECOSYSTEM HEALTH AND VITALITY

Montréal Process Criterion 3 (Montréal Process Working Group 2010); Northern Area Forest Sustainability Indicators 7.1-7.4 (USDA FS 2010d)

The importance of maintaining forest ecosystem health and vitality

Forest ecosystem health depends on stable forest composition and structure and on sustainable ecosystem processes. Forest disturbances that push an ecosystem beyond the range of conditions considered normal can upset the balance among processes, exacerbate forest health problems, and increase mortality beyond historical norms. Sometimes forest ecosystems respond to disturbances by returning to the normal range of conditions. At other times, however, the ecosystem is so altered that it follows a new trajectory—occasionally without historical precedent or known capability for resiliency—producing uncharacteristic changes in forest health and associated processes that may threaten the human, plant, or animal populations that depend on forests. The following sections describe forest health in northern landscapes using indicators based on overall mortality trends and on potential impacts of specific insects and diseases.

Indicators of forest ecosystem health and vitality for northern forests

Mortality

Mortality is a natural process in a forest ecosystem. Dead trees serve valuable ecosystem functions as wildlife habitat, substrate for young

Key Findings for Criterion 3

- Mortality rates are one indicator of forest health. Current statewide mortality rates are 1 to 2 percent of total volume per year.
- The forest-type groups with the greatest percent annual mortality on a volume basis are noncommercial hardwoods, other eastern soft hardwoods, cottonwood and aspen, and other yellow pines.
- The most frequent types of tree defects are advanced decay, cracks or seams in tree boles, cankers, galls, and dead terminal branches.
- Locations where basal area mortality is expected to increase by at least 25 percent over the next 15 years are located throughout the North but are concentrated in the Northeastern States.
- Gypsy moth and emerald ash borer are entrenched invasive species causing widespread mortality.
- Other invasive insect species that have the potential to cause extensive mortality if they become established include the Asian longhorned beetle, Sirex wood wasp, and European spruce bark beetle.

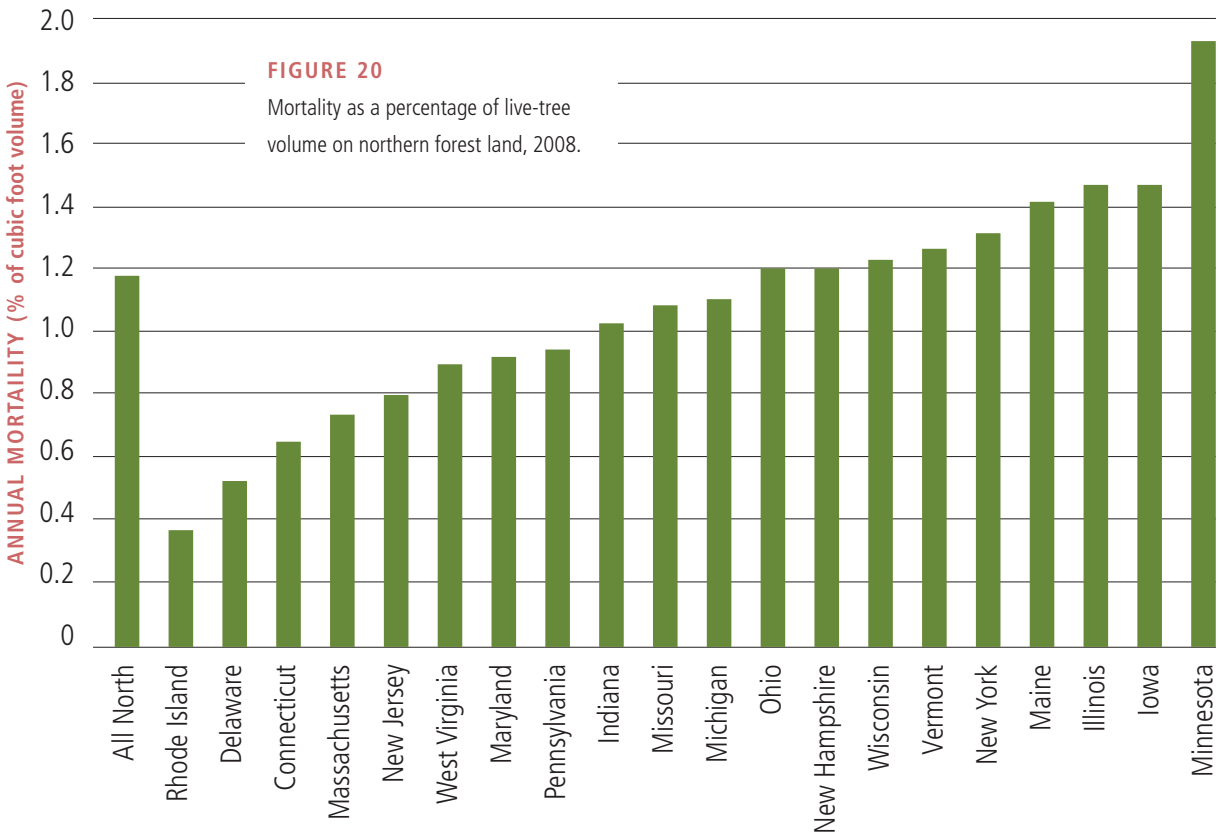


FIGURE 20
Mortality as a percentage of live-tree volume on northern forest land, 2008.

plants, and sources of nutrients for the forest floor. Patterns and trends in mortality give a sense of overall forest health. Uncharacteristic increases in mortality can indicate fundamental forest health issues that may be associated with forest age, climate, insects, diseases, weather events, or other disturbance agents.

In northern forests, statewide mortality as a percentage of current live-tree volume ranged from about 0.4 to 1.5 percent annually (Miles 2010), with the exception of Minnesota at 1.9 percent (Fig. 20). These mortality rates are within the range of the values reported from prior State surveys. A lack of historical data based on consistent sampling methods limits our ability to analyze mortality trends over time.

Mortality percentages by species group for each State provide additional insight into variation across the region (Table 6). Seven species groups—other yellow pines (*Pinus* spp.), American beech (*Fagus grandifolia*), eastern noncommercial hardwoods, spruce (*Picea* spp.) and balsam fir, other eastern soft hardwoods, jack pine, and cottonwood and aspen (*Populus* spp.)—had annual mortality rates in excess of 2 percent. Because the cottonwood and aspen group is dominated by short-lived species, relatively high mortality rates are expected. High mortality rates for many of the other species groups are partly associated with insect and disease agents.

Table 6—Annual mortality of species group as a percent of volume by Northern State, 2008. To reduce uncertainties associated with small sample sizes, mortality for a species group is reported only if the group comprises at least 3 percent of a State's volume of growing stock, but the mortality totals for individual States and for the region as a whole include all species groups. States are ordered from least to greatest mortality percent for all species groups, and species groups are ordered from least to greatest mortality percent for the combined Northern States.

State and Region	All species groups	Yellow-poplar	Tupelo and blackgum	Sweetgum	Loblolly and shortleaf pine	Eastern white and red pine	Hard maple	Select white oaks	Select red oaks	Black walnut	Eastern hemlock	Other eastern softwoods	Soft maple	Hickory
Rhode Island	0.36					0.25		0.02	0.08				0.70	
Delaware	0.51	0.15	0.10	0.55	0.57			0.03					0.66	
Connecticut	0.63					1.00	0.23	0.09	0.22		1.24		0.60	0.04
Massachusetts	0.71					0.38	0.44		0.36		0.16		1.11	
New Jersey	0.77	0.26		0.67				0.22	0.37			0.93	1.33	
West Virginia	0.87	0.44					0.36	0.71	0.71				0.44	1.06
Maryland	0.90	0.43		0.22	0.40			0.61	1.02				1.00	0.61
Pennsylvania	0.92	0.28				1.19	0.94	0.44	0.39		0.91		0.67	
Indiana	1.00	0.55					0.41	0.29	0.93				1.13	0.89
Missouri	1.06				0.35			0.52	1.81	0.60		0.17		0.58
Michigan	1.08					0.32	0.37		0.42			0.61	0.46	
Ohio	1.17	0.47					0.70	0.93	0.16				0.96	0.71
New Hampshire	1.18					0.47	0.61		0.77		0.42		0.85	
Wisconsin	1.20					0.32	0.30	0.65	0.84			0.67	0.54	
Vermont	1.23					0.67	0.68		0.53		0.45		1.13	
New York	1.29					0.81	0.57		0.46		1.11		0.68	
Maine	1.38					0.58	0.79		0.07		0.23	0.80	0.77	
Illinois	1.43						0.18	0.80	2.00	1.01			0.83	0.31
Iowa	1.43							0.65	1.16	0.15			0.91	1.36
Minnesota	1.88					0.51	1.00	0.42	0.91			1.06	0.96	
Northern States	1.15	0.41	0.47	0.47	0.49	0.56	0.58	0.59	0.65	0.69	0.70	0.73	0.73	0.74

Table 6 continued

State and Region	Basswood	Other white oaks	Ash	Other red oaks	Yellow birch	Other eastern hard hardwoods	Other yellow pines	Beech	Eastern noncommercial hardwoods	Spruce and balsam fir	Other eastern soft hardwoods	Jack pine	Cottonwood and aspen
Rhode Island				0.40									
Delaware				0.88							0.77		
Connecticut			1.27	0.65		0.63							
Massachusetts			0.98	0.60		0.43					2.01		
New Jersey		0.32	1.52	1.62		0.61	0.33				2.14		
West Virginia		0.87		0.80		1.57		2.06			1.12		
Maryland		0.44		1.49							1.09		
Pennsylvania		0.77	0.87	0.40		1.51		2.11			1.31		
Indiana			1.07	0.82							2.09		2.23
Missouri		0.63		1.80							1.92		
Michigan			1.47	0.58						2.67	3.08		2.55
Ohio			1.48	0.46				1.03			2.78		1.19
New Hampshire			0.95		1.55			1.75		2.72	3.70		
Wisconsin	0.57		0.65	1.65						3.02	3.41		2.74
Vermont			0.35		0.75			3.12		2.48	2.75		
New York			1.03		1.50			2.58		2.10	2.81		3.42
Maine					0.94			4.34		2.23	2.54		2.35
Illinois			1.66	1.66		1.56					3.55		1.23
Iowa	0.88		1.12	1.09		0.59					4.25		0.80
Minnesota	0.89		0.85							3.02	3.08		3.12
Northern States	0.77	0.77	1.05	1.15	1.26	1.40	2.11	2.35	2.43	2.44	2.45	2.59	2.66

Damage on standing timber

Tree damage is sometimes an indicator of the potential for future mortality. Although not all types of tree damage (e.g., cracks or cankers) result in tree mortality, such factors can weaken a tree and predispose it toward mortality from other causes.

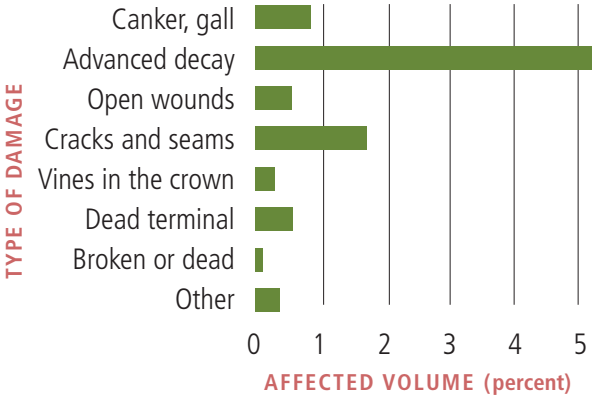
Statewide forest inventories conducted by the U.S. Forest Service have recorded damage on thousands of sampled trees. The bulk of trees in the North are undamaged, but some States have evidence of certain types of damage on up to 5 percent of all trees (Fig. 21). The most prominent damage types were various forms of decay, broken trees, and brooms or cracks.

Insect and disease incidence and risk

Many different insect, disease, invasive plant, and abiotic processes can impact forest ecosystems; sometimes multiple agents act simultaneously on the same forest area. Large cumulative risks can result in forest areas where insect or disease outbreaks appear imminent. Forests at risk span the entire North, but seem particularly concentrated in portions of West Virginia and Pennsylvania (Fig. 22). These are areas where one or more "biotic processes are

FIGURE 21

Percent of total volume on northern forest land by category of forest damage.



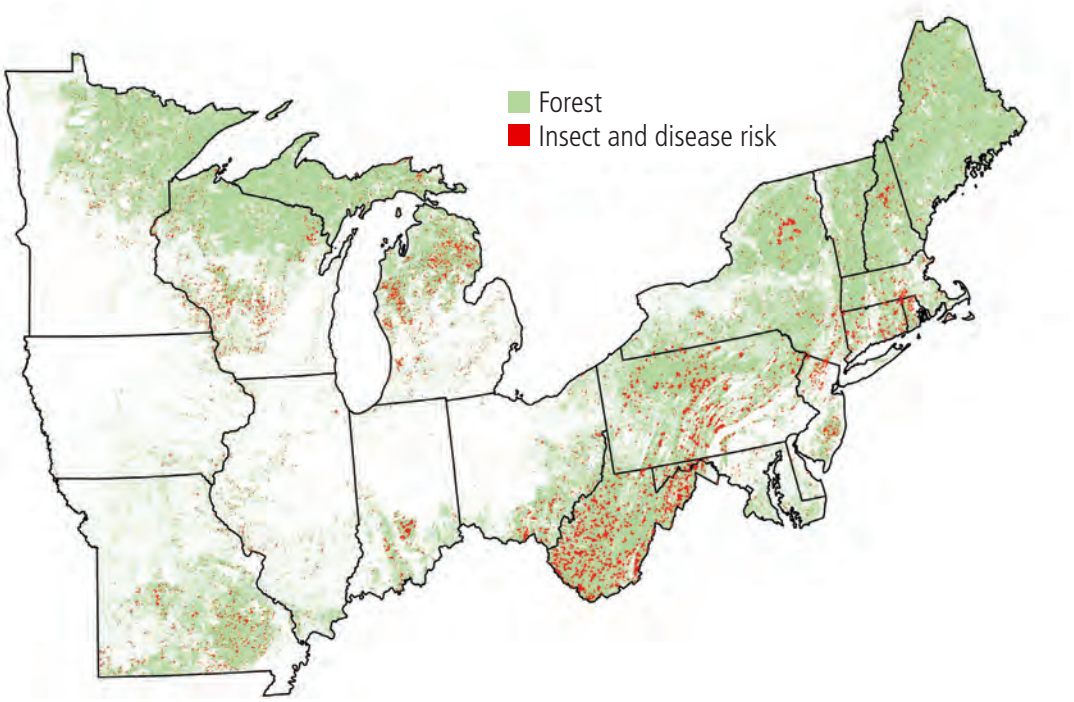
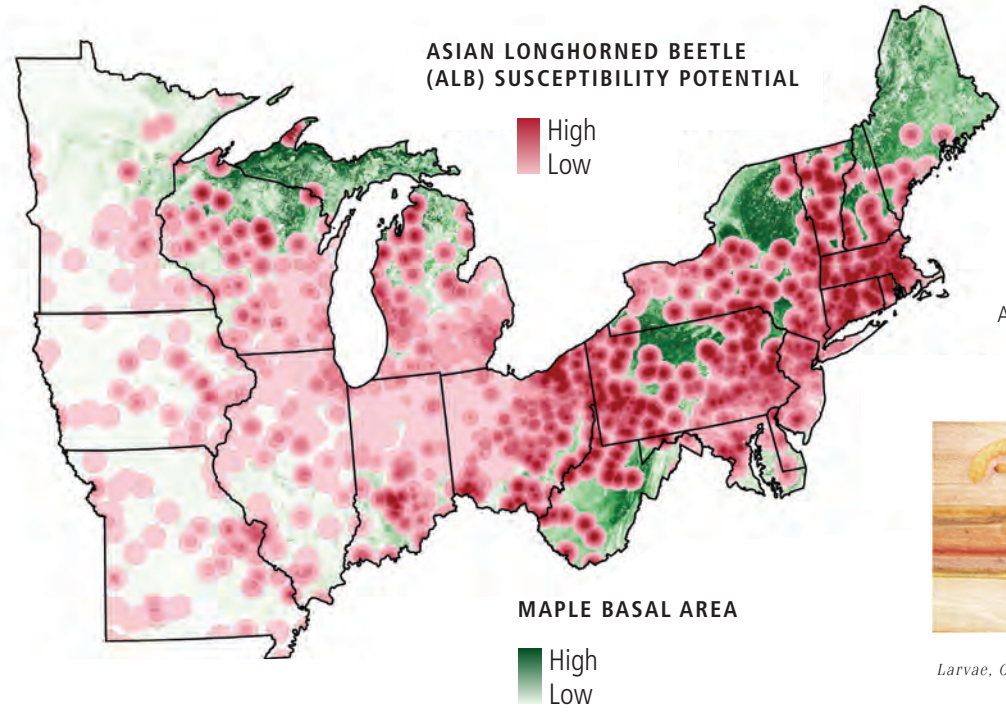


FIGURE 22

Insect and disease risk for northern forests with forest areas in red where 25 percent or more mortality (by basal area) is expected over the next 15 years. Forests at risk span the entire region, but appear particularly concentrated in portions of West Virginia and Pennsylvania. (USDA FS 2011c).

significantly out of range" (USDA Forest Service 2011e). Subsequent paragraphs examine several insect and disease agents in detail.

The Asian longhorned beetle (Fig. 23) is a vigorous, nonnative pest of maples (*Acer* spp.), birches (*Betula* spp.), elms *(Ulmus* spp.), and willows (*Salix* spp.); and it occasionally attacks ashes and poplars (*Populus* spp.). Given the prevalence of these tree species in northern forests and the many potential ports of entry through which the insect could be introduced via imported wooden pallets or shipping containers, the risk from Asian longhorned beetle is widespread (Bancroft and Smith 2001) (Fig. 23), especially for fragmented and stressed forests. Unrestrained infestation has the potential to dramatically alter forest composition, structure, and ecosystem function. The effectiveness of current Asian longhorned beetle quarantine efforts is still being evaluated.



Susceptibility potential relates to introduction and establishment where:

Introduction potential relates to:

1. Commodities associated with ALB interceptions. Associated commodities include bricks, stones, metal, and glass materials shipped (with wood packing/pallets) from countries where ALB exists.

2. Polygon ZIP code centroids that represent businesses and personnel that import and handle the commodities of interest.

Establishment potential relates to:

Mean basal area for all maple (Acer spp.), the host species for ALB, assigned to ZIP code centroids created in the introduction component as well as 30 km buffers to include the cumulative distances that ALB could possibly disperse over a 15-year period at 2 km per year (Bancroft and Smith 2001).

FIGURE 23

Susceptibility of northern forests to Asian longhorned beetle attack (USDA FS 2011a, 2011b).

Larvae, Courtesy of Steven Katovich, USDA Forest Service, Bugwood.org

Adult, Courtesy of Dennis Haugen, USDA Forest Service, Bugwood.org

The emerald ash borer is a nonnative bark-boring beetle that was discovered in southeastern Michigan in 2002 and has since killed tens of millions of ash trees in forests and along streets throughout the Northern States. Figure 24 shows the spatial distribution of the northern ash resource (USDA FS 2010b) and the risk of introduction and establishment (susceptibility) when defined as a geographic function of preferred host range, urban ash trees, proximity of urban ash trees to natural forests, and past rates of phloem insect interceptions at U.S. ports of entry.

With an estimated 15 billion cubic feet of ash volume, ash species represent 5 percent of the volume of all trees in northern forests,

Above Clockwise: 1) Second, third, and fourth stage larvae. 2) Purplish red abdomen on adult emerald ash borer. Photos courtesy of David Cappaert, Michigan State University, Bugwood.org

and all ashes are susceptible to EAB attack. Due to their relative abundance of ash trees, Minnesota, Ohio, and Pennsylvania face the potential for heavy mortality from emerald ash borers. The economic impact of losing ash species is significant. For example, Treiman et al. (2008) estimated that if emerald ash borers become established statewide, Missouri's economy would lose more than $6.7 million annually. The economic impact of losing ash

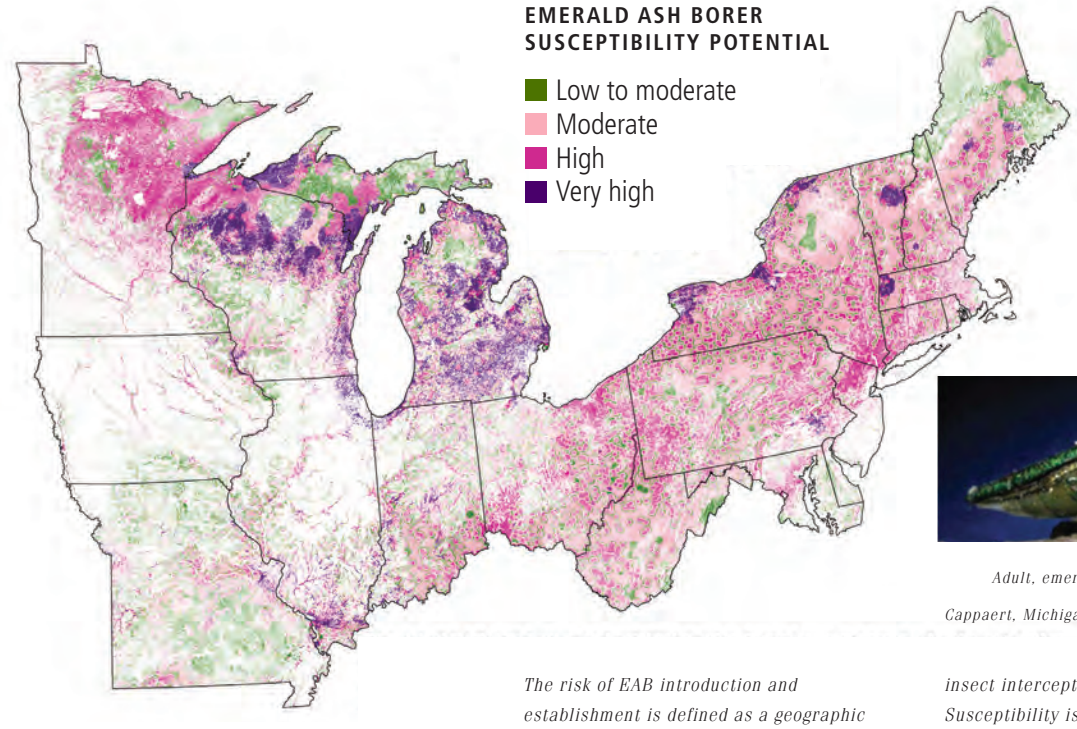


FIGURE 24
Susceptibility of northern forests to attack by emerald ash borer (USDA FS 2011a, 2011b).

Adult, emerald ash borer, Courtesy of David Cappaert, Michigan State University, Bugwood.org

The risk of EAB introduction and establishment is defined as a geographic function of: preferred host range, urban ash forests, proximity of urban ash forests to natural forests, and phloem insect interceptions at U.S. ports of entry. Susceptibility is defined as the potential for introduction and establishment, over a 15-year period, of a forest pest within a tree species or group.

street trees is harder to estimate because the losses would include aesthetic values as well as the cost of removal and replacement, loss of property values, and impact on cooling costs. Again using Missouri as an example, Treiman et al. (2008) calculated a statewide cost of $20.3 million for street tree replacement.

In 2004, the Sirex woodwasp (*Sirex noctilio*) was discovered in a New York forest. It is an invasive insect that vigorously attacks weakened and dead pine trees. It has killed up to 80 percent of the plantations trees that it has attacked in the southern hemisphere, and it threatens considerable forest land in the North where estimated susceptibility is based on forest species composition, density, and proximity to potential ports of entry (Fig. 25). Areas of forest along the eastern seaboard are particularly at risk (Haugen and Hoebeke 2005).

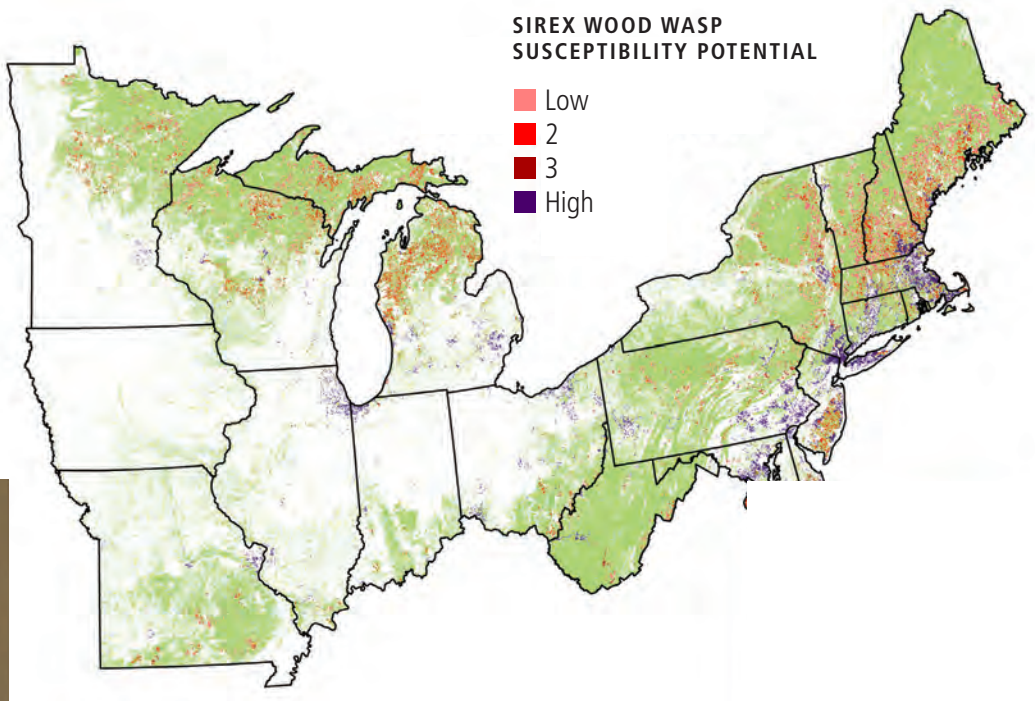
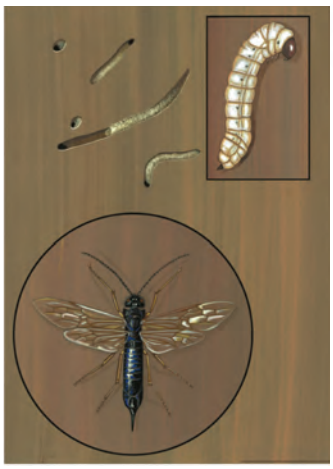


FIGURE 25

Susceptibility of northern forests to Sirex woodwasp. (USDA FS 2011a, 2011b).

Susceptibility is related to the introduction and establishment potential where introduction potential is determined by the locations of the ports that handle commodities with solid wood packing materials shipped from countries where Sirex wood wasp exists as well as distribution centers and markets. Establishment potential is determined by: pine basal area, presence of susceptible host, soil moisture index, and plant hardiness.



Adult, larva, and characteristic damage, Courtesy of Robert Dzwonkow, Bugwood.org

The European gypsy moth (*Lymantria dispar*) continues to devastate North American forests. Introduced in 1868, the species has spread from Boston westward to Wisconsin and southward to Virginia (Figs. 26 and 27). Although gypsy moth larvae prefer hardwoods, they may feed on several hundred different species of trees and shrubs (McManus et al. 1989). In northern forests, larvae prefer oaks, apple (*Malus spp.*), sweetgum (*Liquidambar styraciflua*), alder (*Alnus* spp.), basswood (*Tilia* spp.), birches, poplar, willow, eastern larch (*Larix laricina*), and hawthorn (*Crataegus* spp.).

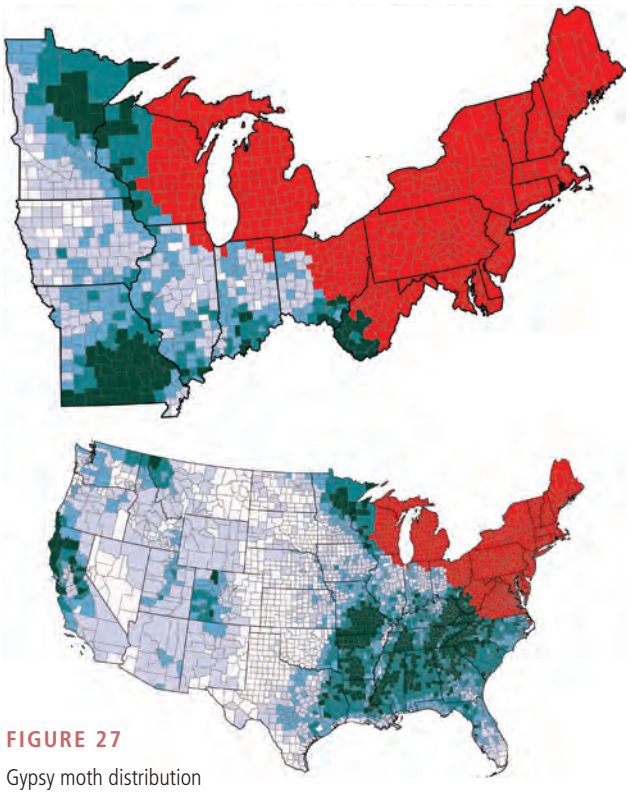


FIGURE 27

Gypsy moth distribution with future risk estimated by volume of host tree species (USDA FS 2011a).

FIGURE 26

Gypsy moth spread by year across the Northern States (USDA FS 2011d).

The list of hosts will likely expand as the insect spreads south and west. Although the invasion "front" experiences the most radical change in stand composition and tree mortality, outbreaks also recur in areas behind the front (Fig. 28). Intensive efforts to "slow the spread" through targeted treatment protocols have significantly reduced, but not stopped, the advance of this insect.

The hemlock wooly adelgid is a small aphid-like insect that feeds on the needles of eastern hemlocks (*Tsuga canadensis*) and Carolina hemlocks (*T. caroliniana*). Comprising 4 percent of all forest volume in northern forests, hemlocks fulfill critical roles within specific ecological niches (Godman and Lancaster 1990) such as provision of winter shelter and bedding for eastern white tailed deer (*Odocoileus virginianus*).

First discovered in Richmond, Virginia, the hemlock wooly adelgid has spread throughout the eastern United States since 1951 (Fig. 29), infesting anywhere from 25 percent (Morin et al. 2005) to 50 percent (USDA FS 2005) of the hemlock range. Young hemlock wooly adelgid nymphs (crawlers) can be spread by wind, on the feet of birds, or in the fur of small mammals (McClure 1990). Once settled, crawlers feed on stored starches in the twigs at the base of hemlock needles, quickly developing through the four nymph life stages and maturing in June. Hemlock decline and mortality typically occur within 4 to 10 years of infestation in the insect's northern range (3 to 6 years in its southern range). Hemlocks that are stressed by drought, poor site conditions, or attacks by other insects and diseases can decline and die more rapidly (USDA FS 2005).

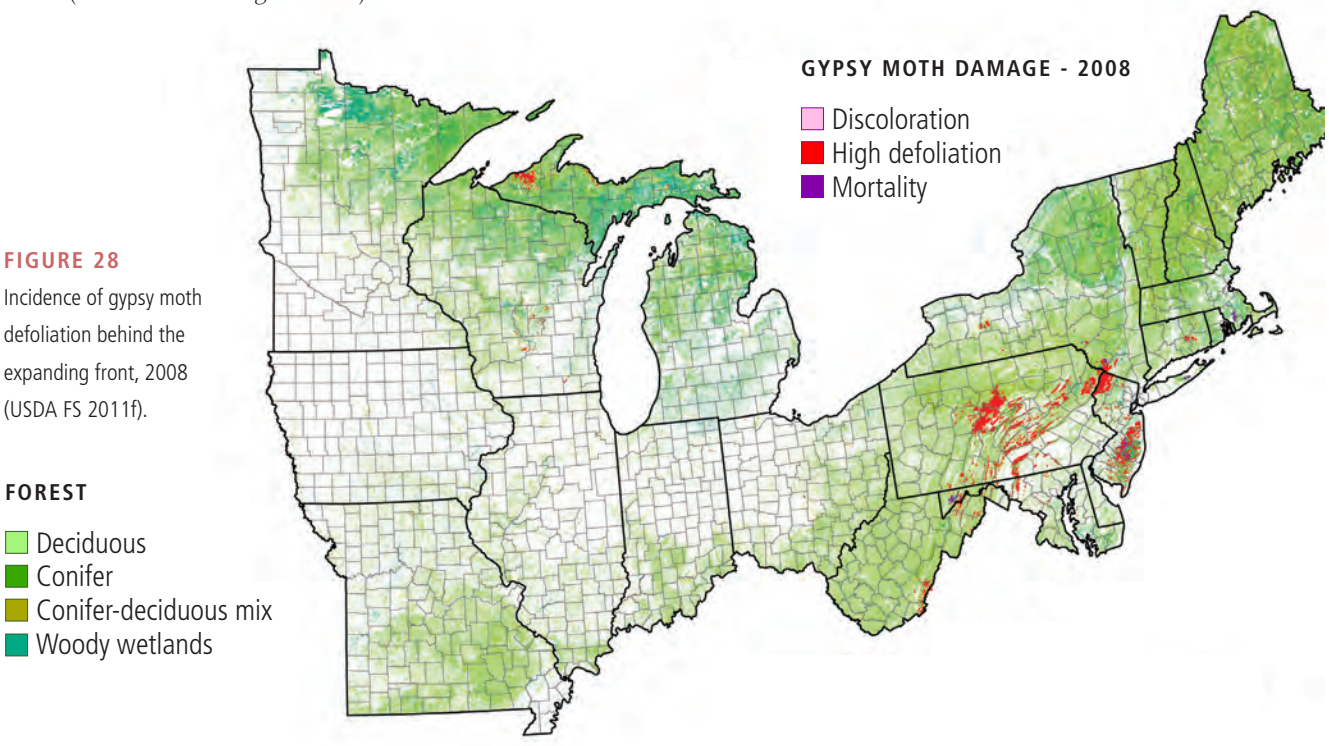


FIGURE 28
Incidence of gypsy moth defoliation behind the expanding front, 2008 (USDA FS 2011f).

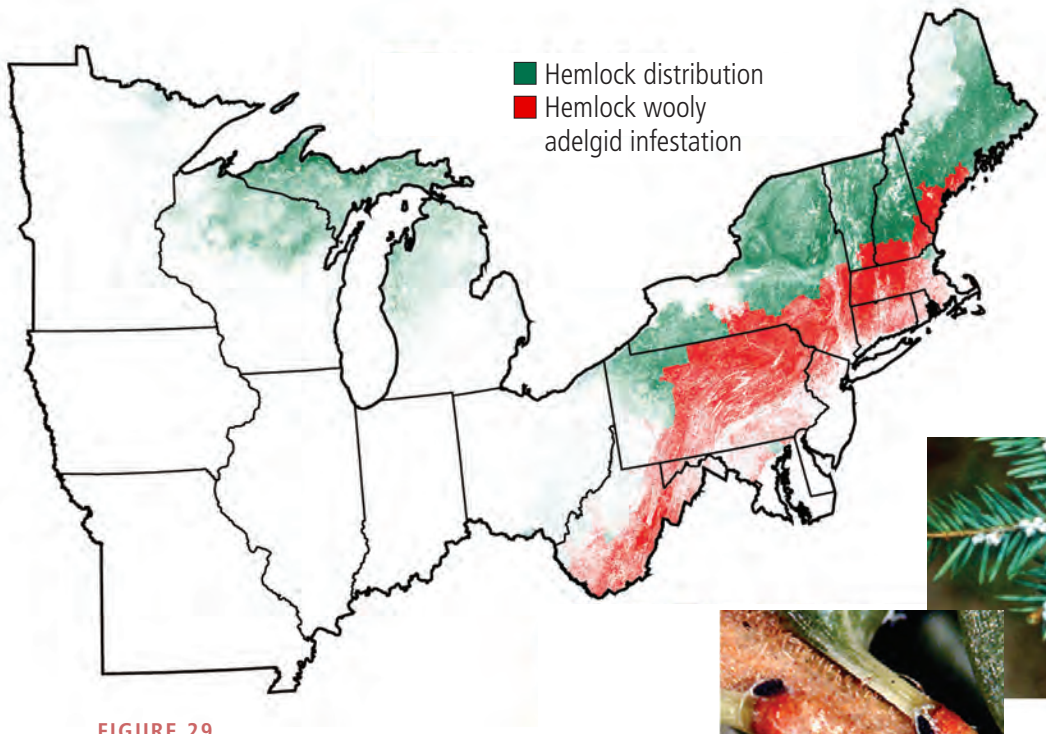


FIGURE 29

Distribution of eastern hemlock and areas infested with hemlock woolly adelgid in the Northern States; the map does not provide information below the county level and viewers should not assume 100 percent infestation in highlighted areas (source U.S. Forest Service-Northeastern Area http://na.fs.fed.us/fhp/hwa/maps/distribution.shtm).

Adelgid ovisacs

USDA Forest Service archives

Nymphs in dormancy

USDA Forest Service archives

European spruce bark beetle (*Ips typographus*), a devastating killer of spruces, is probably capable of successfully invading any of the spruces indigenous to North America. Similar to indigenous bark beetle species, the spruce bark beetle would be extremely difficult to eradicate if it became established in North America. An outbreak in Germany after World War II resulted in a loss of more than 1 billion cubic feet of spruce. Subsequent attacks have devastated spruce forests in Norway, Sweden, Germany (again), and the Czech Republic. In addition to spruces, some species of fir, pine, and larch are known to be susceptible to spruce bark beetle attacks. From 1985 to 2000, spruce bark beetles were intercepted 286 times in packing materials entering U.S. ports (Haack 2001) including Erie, PA (1993), Camden, NJ (1994) and Burns Harbor, IN (1995). This insect has a relatively high reproductive potential; because it breeds under the bark of host trees and is similar to several indigenous bark beetle species, infestations could go undetected for several years.

Substantial acreages of northern boreal forest are potentially susceptible to the European spruce bark beetle. Maine and Minnesota have a large spruce component, which could provide a large volume of suitable host material that would

allow rapid spread in forests (Fig. 30) as well as yard and street tree plantings. Although not yet established in the United States, the European spruce bark beetle is considered a high-risk invasive species because of abundant host trees, host trees in proximity to ports of entry, and difficulty in controlling established populations. It has the potential to greatly exacerbate insect mortality in spruce-fir forests, which are already afflicted by periodic outbreaks of spruce budworm (*Choristoneura fumiferana*), that result in millions of cubic feet of lost timber with associated ecological and economic consequences.

Numerous other insects and diseases undermine the health, value, and diversity of northern forests. Some are well entrenched invasives: beech scale insect, chestnut blight, Dutch elm disease, and dogwood anthracnose. Thousand cankers disease of black walnut recently was found in Tennessee. Sudden oak death (*Phytophthora ramorum*) is a worrisome future possibility. Oak decline, hickory decline, oak tatters, tubakia leaf spot, and bacterial leaf scorch are other disease complexes of concern in northern forests.

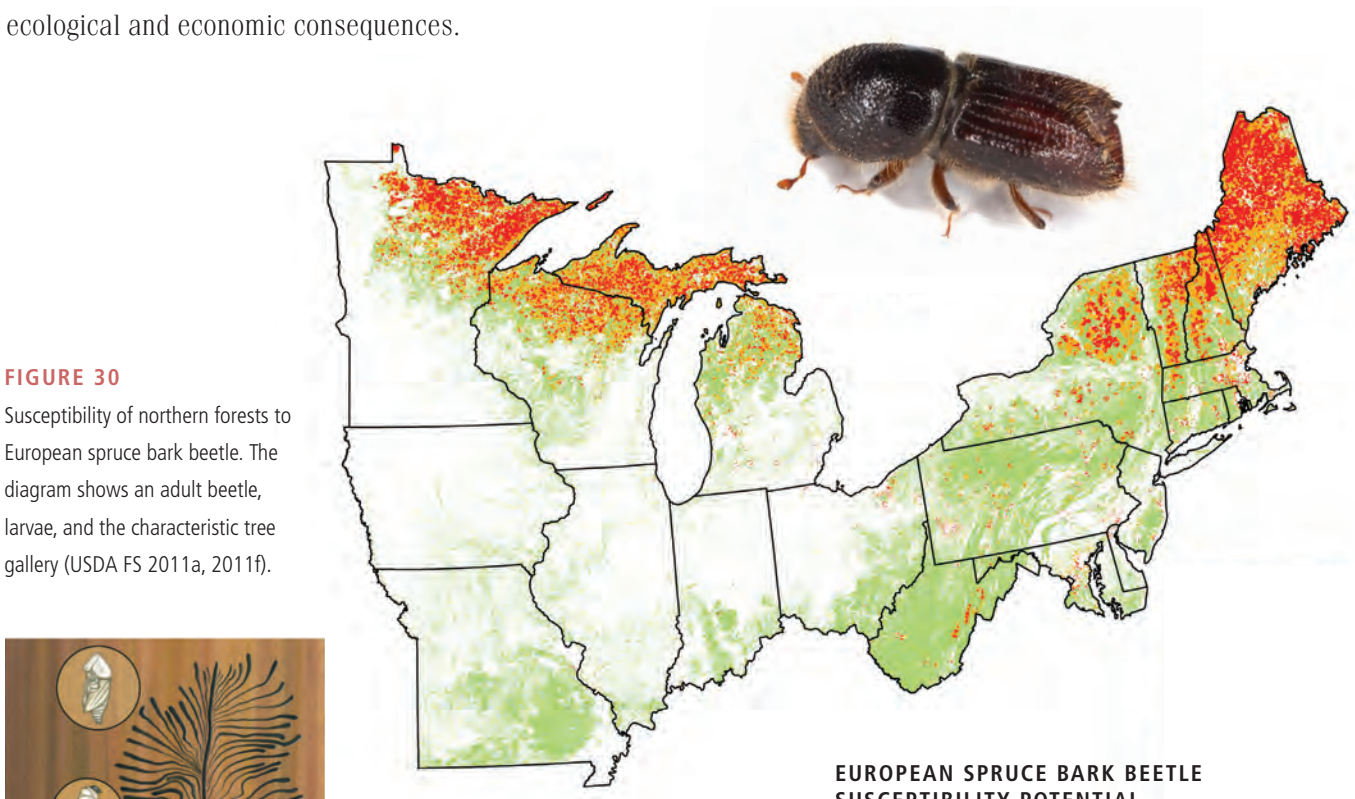


FIGURE 30

Susceptibility of northern forests to European spruce bark beetle. The diagram shows an adult beetle, larvae, and the characteristic tree gallery (USDA FS 2011a, 2011f).

Courtesy of Robert Dzwonkow, Bugwood.org

Criterion 4:

CONSERVATION AND MAINTENANCE OF SOIL AND WATER RESOURCES

Montréal Process Criterion 4 (Montréal Process Working Group 2010); Northern Area Forest Sustainability Indicators 8.1-8.5, 9.1-9.2 (USDA FS 2010d)

The importance of conservation and maintenance of soil and water resources

Soils

Soils are the fundamental resource enabling land to provide a wide array of benefits. Both humans and wildlife rely on soils for the production of life-sustaining nourishment and shelter. Soil is important to society because it supports plants that supply food, fibers, drugs, and other essentials and because it filters water and recycles wastes.

Broadly defined, soil is the natural medium for the growth of land plants, regardless of their size structure or species composition. Narrowly defined, soil is a natural body comprised of solids (minerals and organic matter), liquids, and gases that occurs on the land surface, occupies space, and has at least one of the following characteristics: (1) horizons (or

Key Findings for Criterion 4

- 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.
- Forests in the North have the capacity to supply about 280 billion m^3 (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. Locations of concern include New Jersey, Delaware, and Ohio; and southern Illinois, Indiana, Michigan, Minnesota, and New Hampshire.

layers) that are distinguishable from the initial material and form a multiphase matrix resulting from additions, losses, transfers, and transformations of energy and matter; (2) the ability to support rooted plants in a natural environment (USDA NRCS 2010). The relative proportions of minerals, organic matter, water, and air largely determines the ability of the soil to support plant life (O'Neill et al. 2005).

Soil classification is based on soil properties observed in the field, inferred from field observations, or measured in a laboratory (USDA NRCS 2006). The general soil association units that occur in repeatable patterns on the landscape are mapped from broad-based soil inventories (USDA NRCS 2010). Figure 31 shows the distribution of the principal soil kinds in the North and the contiguous United States as classified and developed by the National Cooperative Soil Survey.

FIGURE 31
General soil map for the Northern States and the conterminous United States (USDA NRCS 2011).

Soil quality refers to the capacity of a soil to sustain biological productivity, maintain environmental quality, and promote plant and animal health (Doran and Parkin 1994). Concise definitions for soil quality include "fitness for use" and "the capacity of a soil to function." Combining these, soil quality is the ability of a soil to perform the functions necessary for its intended use. Soil functions include sustaining biological diversity, activity, and productivity; regulating water and solute flow; filtering, buffering, and degrading organic and inorganic materials; storing and cycling nutrients and carbon; and providing physical stability and support (Kuykendall 2008). Soil quality and land management both have a direct influence on water and atmospheric quality and, by extension, human and animal health (Doran and Parkin 1994, Kennedy and Papendick 1995).

Soil quality information helps answer several key questions about: (1) the productivity and sustainability of forest systems, (2) the conservation of soil and water resources, (3) the accumulation of persistent toxic substances, and (4) the contribution of forested systems to the global carbon cycle (O'Neill et al. 2005). For forestry as well as agriculture, maintenance of site productivity is vital to sustainable management.

Water

The factors that affect water quality and supply in forest ecosystems include climate and hydrology, catchment geology, natural disturbances, land management, and actual land-use activities. Water quality in undisturbed forested catchments can provide important baseline references for monitoring physical, chemical, or biological trends in catchments that have varying levels of land use, and can identify management activities that need to be altered to preserve water quality (USDA FS 2009a). The quality and quantity of runoff have long been a focus of forest management, which can have beneficial as well as detrimental effects, depending on the objectives, timing, techniques, and size of operations.

Much of the North's highest quality water supplies originate in forests (Brown and Binkley 1994). Forested watersheds provide

water purification, mitigation of floods and droughts, soil retention, and habitat maintenance. Surface water runoff in forest environments is rare with most rainfall and snowmelt moving into streams through subsurface flows, accelerating nutrient uptake, cycling, and contaminant absorption processes. The quality and abundance of fresh water in lakes, wetlands, streams, and rivers determine aquatic and terrestrial species biodiversity.

Forests are crucial to the protection of drinking water (Barnes et al. 2009). Managing forests for clean water production will grow in importance as the northern populations and water demand both increase. The water resource is also one of the many attractions for swimming, boating, canoeing, fishing, and other water-based activities. The enjoyment of these activities depends directly on the quality of the water resource. In addition, aquatic as well as terrestrial wildlife species depend on the water resource.

The North is characterized by a cool-moist-temperate climate, associated with the Lake States and higher elevations of the eastern Continental Divide. Although seasonally variable, these conditions produce large volumes of fresh water that support production of forest vegetation, provide water-based recreation opportunities, and supply the region's drinking water. Northern landscapes support the headwaters of most major eastern rivers, including the Mississippi. In the lower 48 States, although highlands and mountains constitute a relatively small land area proportion, they serve as "water towers" with water supplies originating at the tops of watersheds.

Water supplies and their uses are affected by population growth, economic trends, legal decisions, and climatic extremes such as droughts. Water is in effect a finite resource because few approaches for dramatically augmenting current water supplies are ecologically or economically viable (Barnes et al. 2009). While water shortages and restrictions are regular news in the West, they also occur in the North, particularly in urban areas. In addition to drought, the primary threat to water supplies in the North is loss of forest to development, agriculture, or other land uses.

As private lands continue to be developed, public and other protected forest lands will become more important as sources of high quality water.

Indicators of soil and water resource conservation for northern forests

Soil quality

Some disturbances and management practices can degrade forest ecosystem health and productivity by changing soil chemical or physical properties. As part of its Forest Inventory and Analysis plot network the Forest Service implements a national forest-soil monitoring program to address specific questions about the long-term sustainability of the Nation's forest soil resources (USDA FS 2011g). Although many soil and water metrics are available to gauge forest health (O'Neill et al. 2005), the focus here for northern forests is on chemical changes, compaction, and erosion.

Figure 32 shows the spatial distribution of calcium to aluminum (Ca:Al) molar ratios in northern forests. The map serves as a coarse filter for anticipating soils-related threats to forest health, one of which is increasing acidity in association with a decreasing Ca:Al ratio (indicating smaller calcium reserves and potentially toxic levels of exchangeable aluminum). This soil condition is strongly related to atmospheric acid deposition. Nutrient-poor and acidic forest soil conditions are found throughout the United States, but highly acidic soils with low calcium and high aluminum levels are concentrated in the Northeastern States and southward along the Appalachian Mountains. A continued decrease in the Ca:Al ratio could put calcium-sensitive tree species at risk of decline and die-off, with other site-specific factors influencing the outcome at any given location. Forests on soils with a low Ca:Al ratio may be

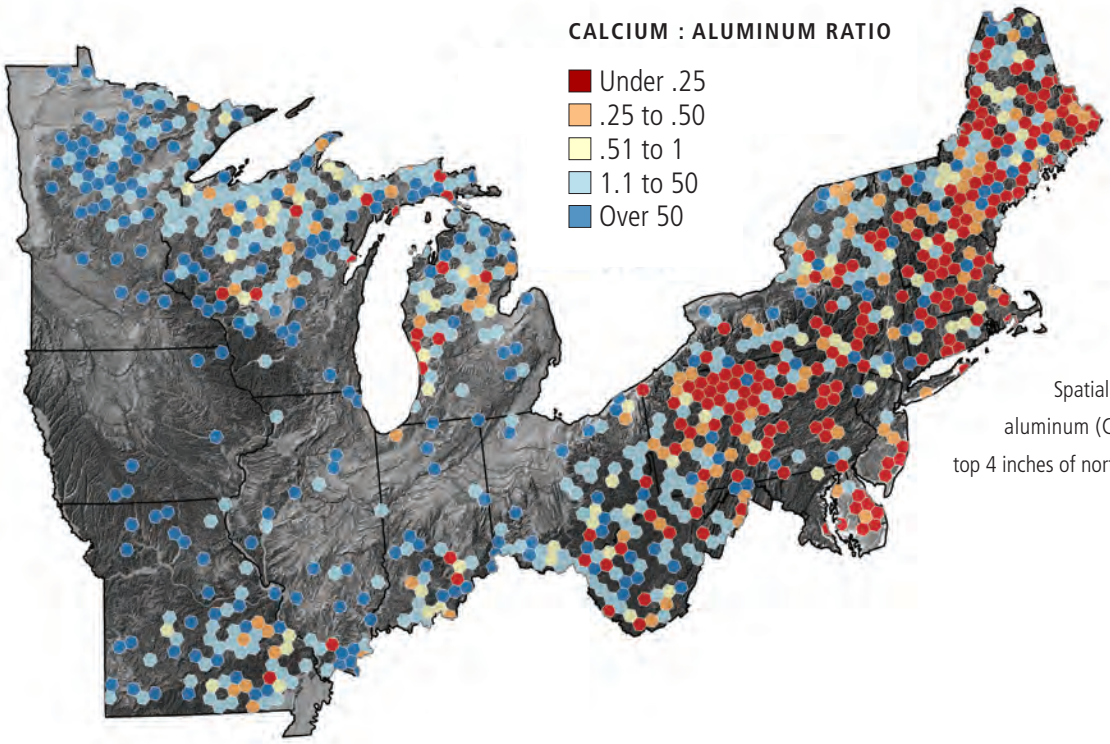


FIGURE 32
Spatial distribution of calcium to aluminum (Ca:Al) molar ratios in the top 4 inches of northern forest soils, 2000 to 2004 (USDA FS 2011g).

more susceptible to damage from additional stressors such as industrial inputs, drought, insects, and diseases (Cronan and Grigal 1995).

Forests protect the soil both directly and indirectly from wind and water erosion. Sites with exposed soil are at highest risk of accelerated soil erosion, but they represent only a small fraction of all forested lands. Although most forest inventory plots have at least some bare soil, few (0.4 to 5.5 percent) have more than 50-percent bare soil. Estimates of bare soil as a percentage of the forest floor provide an indirect measure of potential soil erosion, which reduces soil fertility, has offsite impacts, and decreases land values. Wind-caused erosion is rare in wooded areas, which are protected by forest canopy, strong soil tree root anchor support, and forest floor mulch (tree litter).

Soil compaction reduces pore space and decreases the volume of air in the soil. Compaction occurs when the mineral portion of the soil becomes compressed by heavy equipment or by repeated passes of light equipment, people, or animals. Only 0.3 to 4.7 percent of observed forest monitoring plots show evidence of compaction on more than half the plot area (Fig. 33). Thus, soil compaction is not so much a widespread problem on forested lands as it is a seemingly localized phenomenon that is largely confined to trails (walking, biking, hiking, equestrian, and motorized) and forest harvest operations (USDA FS 2011g).

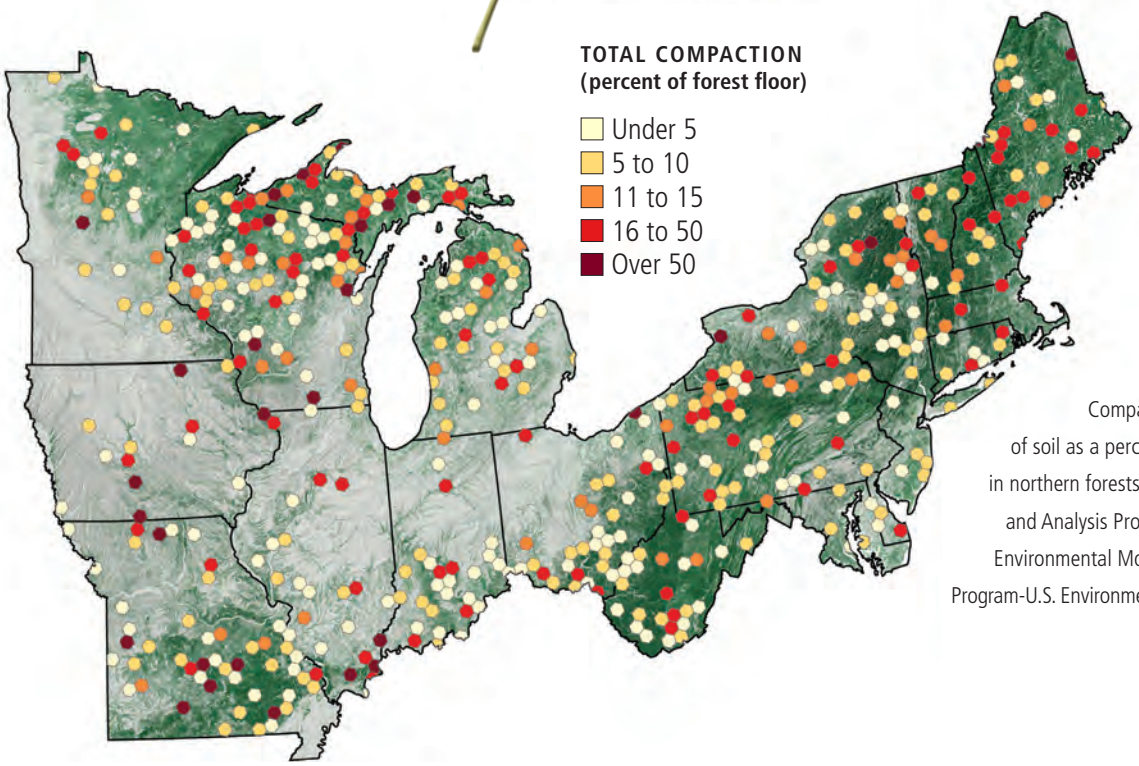


FIGURE 33
Compaction in the top 4 inches of soil as a percentage of the forest floor in northern forests (source: Forest Inventory and Analysis Program, U.S. Forest Service; Environmental Monitoring and Assessment Program-U.S. Environmental Protection Program).

Autumn colors surround the Glade Creek Grist Mill in West Virginia

Compaction can have a variety of negative effects on soil fertility. Reduction in pore space makes the soil more dense and difficult to penetrate, and can constrain the size, reach, and extent of root systems; this can lead to structural failure of plants and destabilization of entire trees. Reduction in soil aeration and movement of fluids can reduce the ability of roots to absorb water, nutrients, and oxygen, thus resulting in shallow rooting and stunted tree forms. At the landscape scale, destruction of soil structure can limit water infiltration, resulting in increased runoff and of soil loss from erosion. In addition to changes in soil physical properties, compaction can also significantly impact biological and chemical processes occurring in the soil. For example, by reducing the oxygen content below what is required for adequate respiration, severe compaction can disrupt root metabolism and move the soil toward an anaerobic condition (O'Neill et al. 2005).

Water supply and quality

Brown et al. (2008) have estimated annual water supply (precipitation minus evapotranspiration) for the conterminous United States (Fig. 34). The areas of largest water supply in the North are associated with dense forest cover (compare Fig. 34 with Figs. 1 and 4), particularly in the highlands and mountains that serve as natural water towers

An estimated 48 percent of the northern water supply originates on forest lands (Table 7), which cover 42 percent of the region's surface area, Approximately 6 percent of the northern water supply originates on Federal forest land, including 5 percent on national forests and national grasslands. The remaining 94 percent of the water supply from northern forests originates on from State and private lands (Table 8), compared to 65 percent for western forests. Public forest lands dominate in the West, where 66 percent of forests are in Federal ownership and 51 percent are national forests and national grasslands.

FIGURE 34

Yearly average water supply (precipitation minus evapotranspiration) by counties in the (A) Northern States and (B) conterminous United States (Brown et al. 2008).

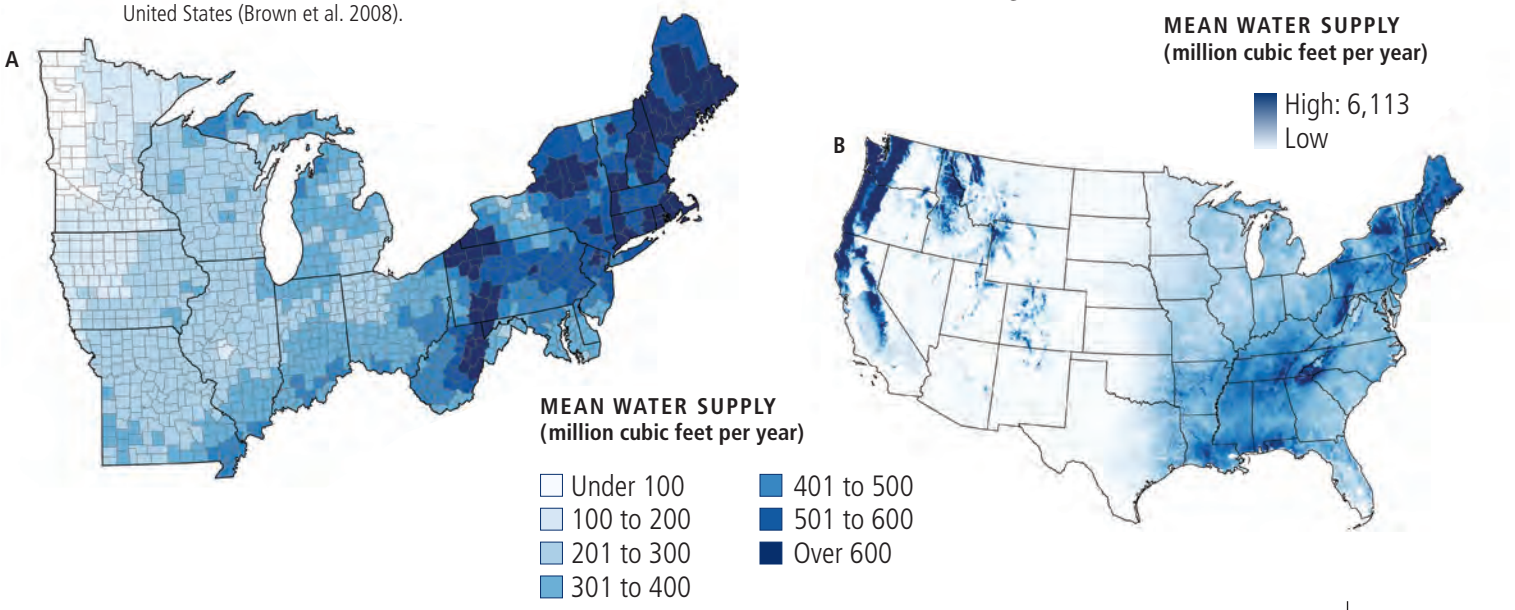


Table 7—Annual water supply in the conterminous United States by land cover class, region, and State (Brown et al. 2008). Proportions by column are given for regions and U.S. totals. Note that 1 million cubic meters of water is equivalent to approximately 811 acre-feet or 264 million gallons.

State and region	Forest	Rangeland	Agriculture	Water-wetland	Other	Total
	(million cubic meters)					
Connecticut	4,466	0	766	771	1,691	7,694
District of Columbia	18	0	0	0	63	81
Delaware	529	0	976	377	106	1,988
Iowa	2,393	1,772	25,327	863	945	31,300
Illinois	5,691	326	29,864	2,005	2,184	40,070
Indiana	6,442	135	22,887	999	1,273	31,736
Massachusetts	7,375	16	643	1,508	2,546	12,088
Maryland	4,087	0	3,732	971	829	9,619
Maine	40,569	291	2,411	5,318	2,281	50,870
Michigan	19,776	1,004	14,723	9,701	1,681	46,885
Minnesota	6,346	203	12,477	7,995	805	27,826
Missouri	14,842	209	31,852	2,274	1,542	50,719
New Hampshire	12,072	0	768	1,107	735	14,682
New Jersey	4,214	0	1,852	1,383	2,226	9,675
New York	43,133	0	14,240	3,944	3,754	65,071
Ohio	12,748	8	20,691	1,082	2,214	36,743
Pennsylvania	41,310	0	15,707	1,107	3,237	61,361
Rhode Island	1,198	0	53	242	345	1,838
Vermont	10,203	13	1,799	773	374	13,162
Wisconsin	14,760	155	15,944	4,659	889	36,407
West Virginia	26,548	0	3,639	195	700	31,082
North total	278,720	4,132	220,351	47,274	30,420	580,897
Proportion of North (percent)	48	1	38	8	5	100
Alabama	47,321	0	14,545	5,538	3,010	70,414
Arkansas	27,245	69	24,148	6,119	1,303	58,884
Florida	15,094	3,947	7,124	12,822	5,481	44,468
Georgia	35,955	116	13,252	6,133	4,472	59,928
Kentucky	29,720	0	16,728	1,613	1,323	49,384
Louisiana	18,217	278	17,182	17,506	2,434	55,617

Table 7 continued

State and region	Forest	Rangeland	Agriculture	Water-wetland	Other	Total
	(million cubic meters)					
Mississippi	32,512	10	21,885	8,506	2,320	65,233
North Carolina	34,087	0	11,540	6,122	2,580	54,329
Oklahoma	6,388	5,887	9,429	1,361	704	23,769
South Carolina	15,671	0	6,336	4,275	2,041	28,323
Tennessee	38,059	0	18,392	2,663	2,695	61,809
Texas	13,023	8,945	24,202	6,101	3,758	56,029
Virginia	25,743	0	8,817	1,876	1,719	38,155
South total	339,035	19,252	193,580	80,635	33,840	666,342
Proportion of South (percent)	51	3	29	12	5	100
East total (North and South)	617,755	23,384	413,931	127,909	64,260	1,247,239
Proportion of East (percent)	50	2	33	10	5	100
California	53,574	28,587	6,664	784	3,438	93,047
Oregon	78,293	7,899	6,679	977	3,931	97,779
Washington	87,885	7,695	3,032	2,898	11,641	113,151
Pacific Coast total	219,752	44,181	16,375	4,659	19,010	303,977
Proportion of Pacific Coast (percent)	72	15	5	2	6	100
Arizona	1,927	2,734	5	5	37	4,708
Colorado	9,453	11,301	508	224	1,073	22,559
Idaho	38,182	15,756	3,506	863	2,758	61,065
Kansas	378	5,283	9,834	579	390	16,464
Montana	27,805	15,167	2,509	546	2,593	48,620
North Dakota	9	951	2,899	200	30	4,089
Nebraska	16	3,769	7,178	366	171	11,500
New Mexico	2,537	2,826	74	11	38	5,486
Nevada	998	4,582	34	35	149	5,798
South Dakota	51	923	3,736	266	40	5,016
Utah	4,261	5,061	178	111	325	9,936
Wyoming	8,077	10,009	391	730	2,017	21,224
Interior West total	93,694	78,362	30,852	3,936	9,621	216,465
Proportion of Interior West (percent)	43	36	14	2	4	100
West total (Pacific and Interior)	313,446	122,543	47,227	8,595	28,631	520,442
Proportion of West (percent)	60	24	9	2	5	100
Conterminous U.S. total	931,201	145,927	461,158	136,504	92,891	1,767,681
Proportion of Conterminous U.S. (percent)	53	8	26	8	5	100

Table 8—Annual water supply in the conterminous United States by ownership, region, and State (Brown et al 2008). Proportions by column are given for regions and U.S. totals. Note that 1 million cubic meters of water is equivalent to approximately 811 acre feet or 264 million gallons.

State and Region	National Forest System	Bureau of Land Management	National Park Service	Bureau of Indian Affairs	Other Federal	State and Private	Total
	(million cubic meters)						
Connecticut	0	0	0	0	10	7,683	7,694
District of Columbia	0	0	6	0	3	72	81
Delaware	0	0	0	0	39	1,950	1,989
Iowa	0	0	1	4	153	31,141	31,299
Illinois	1,451	0	0	0	272	38,347	40,070
Indiana	1,005	0	9	0	378	30,345	31,737
Massachusetts	2	0	22	0	142	11,922	12,088
Maryland	0	0	80	0	146	9,393	9,619
Maine	199	0	65	79	184	50,343	50,870
Michigan	6,569	0	76	289	392	39,560	46,886
Minnesota	2,505	0	173	1,145	164	23,839	27,826
Missouri	3,490	0	130	0	458	46,642	50,720
New Hampshire	2,715	0	0	0	35	11,932	14,682
New Jersey	0	0	93	0	240	9,343	9,676
New York	30	0	15	164	420	64,441	65,070
Ohio	1,432	0	50	0	132	35,130	36,744
Pennsylvania	1,783	0	84	0	245	59,249	61,361
Rhode Island	0	0	0	0	10	1,828	1,838
Vermont	1,915	0	0	0	97	11,150	13,162
Wisconsin	2,177	0	85	668	220	33,257	36,407
West Virginia	4,990	0	132	0	136	25,824	31,082
North total	30,263	0	1,021	2,349	3,876	543,391	580,900
Proportion of North (percent)	5	0	0	0	1	94	100
Alabama	2,852	0	45	0	902	66,615	70,414
Arkansas	6,170	0	128	0	1,263	51,323	58,884
Florida	2,149	0	303	103	1,982	39,930	44,467
Georgia	5,329	0	53	0	1,676	52,870	59,928
Kentucky	4,183	0	204	0	874	44,123	49,384
Louisiana	1,713	0	38	1	1,379	52,485	55,616
Mississippi	5,303	0	7	35	828	59,060	65,233
North Carolina	8,825	0	1,031	170	1,180	43,123	54,329

Table 8 continued

State and Region	National Forest System	Bureau of Land Management	National Park Service	Bureau of Indian Affairs	Other Federal	State and Private	Total
	(million cubic meters)						
Oklahoma	714	0	7	864	866	21,318	23,769
South Carolina	2,034	0	34	0	621	25,634	28,323
Tennessee	2,949	0	1,036	0	1,864	55,960	61,809
Texas	2,373	0	157	3	1,000	52,496	56,029
Virginia	5,398	0	517	0	567	31,673	38,155
South total	49,992	0	3,560	1,176	15,002	596,610	666,340
Proportion of South (percent)	8	0	1	0	2	90	100
East total (North and South)	80,255	0	4,581	3,525	18,878	1,140,001	1,247,240
Proportion of East (percent)	6	0	1	0	2	91	100
California	43,317	5,096	5,878	978	1,568	36,210	93,047
Oregon	43,016	9,212	474	1,049	302	43,727	97,780
Washington	46,950	42	15,963	2,891	2,227	45,080	113,153
Pacific Coast total	133,283	14,350	22,315	4,918	4,097	125,017	303,980
Proportion of Pacific Coast (percent)	44	5	7	2	1	41	1.00
Arizona	2,517	213	93	949	35	902	4,709
Colorado	15,384	1,509	478	107	75	5,006	22,559
Idaho	41,372	3,498	131	1,755	297	14,011	61,064
Kansas	0	0	7	92	218	16,147	16,464
Montana	29,805	1,084	4,057	2,855	234	10,584	48,619
North Dakota	84	1	3	78	51	3,871	4,088
Nebraska	47	0	8	155	51	11,239	11,500
New Mexico	2,468	286	11	365	70	2,287	5,487
Nevada	2,159	2,698	71	46	243	581	5,798
South Dakota	146	2	12	502	26	4,328	5,016
Utah	6,903	801	34	133	27	2,040	9,938
Wyoming	11,270	1,578	4,542	539	127	3,168	21,224
Interior West total	112,155	11,670	9,447	7,576	1,454	74,164	216,466
Proportion of Interior West (percent)	52	5	4	3	2	34	100
West total (Pacific and Interior)	245,438	26,020	31,762	12,494	5,551	199,181	520,446
Proportion of West (percent)	47	5	6	2	1	38	100
Conterminous U.S. total	325,693	26,020	36,343	16,019	24,429	1,339,182	1,767,686
Proportion of conterminous U.S. (percent)	18	1	2	1	1	76	100

More than 52 million people and nearly 1,600 community water systems utilize surface water for municipal drinking water (Barnes et al. 2009). These water supplies are protected largely by private forest lands. Figure 35 illustrates the relative capacity of northern watersheds to produce clean water in juxtaposition to locations of private and public forests.

Many people are unaware of the threats and vulnerabilities to their water, or the connection between clean water and the extent and condition of the forests at the source of their water supplies (Barnes et al. 2009). Figure 36 displays an index of watershed indicators (US EPA 1996b, 2002) that characterizes the condition, vulnerability, and data sufficiency of the aquatic systems in each of 2,111 watersheds in the lower 48 United States. It provides a summary measure of overall watershed health based on 18 indicator variables (US EPA 2010), with three watershed condition scores (better water quality, water quality with less serious problems, and water quality with more serious problems), and two vulnerability scores (high and low).

About 23 percent of the 540 northern watersheds experienced more serious water quality problems with low vulnerability, 35 percent experienced less serious water quality problems with low vulnerability, and

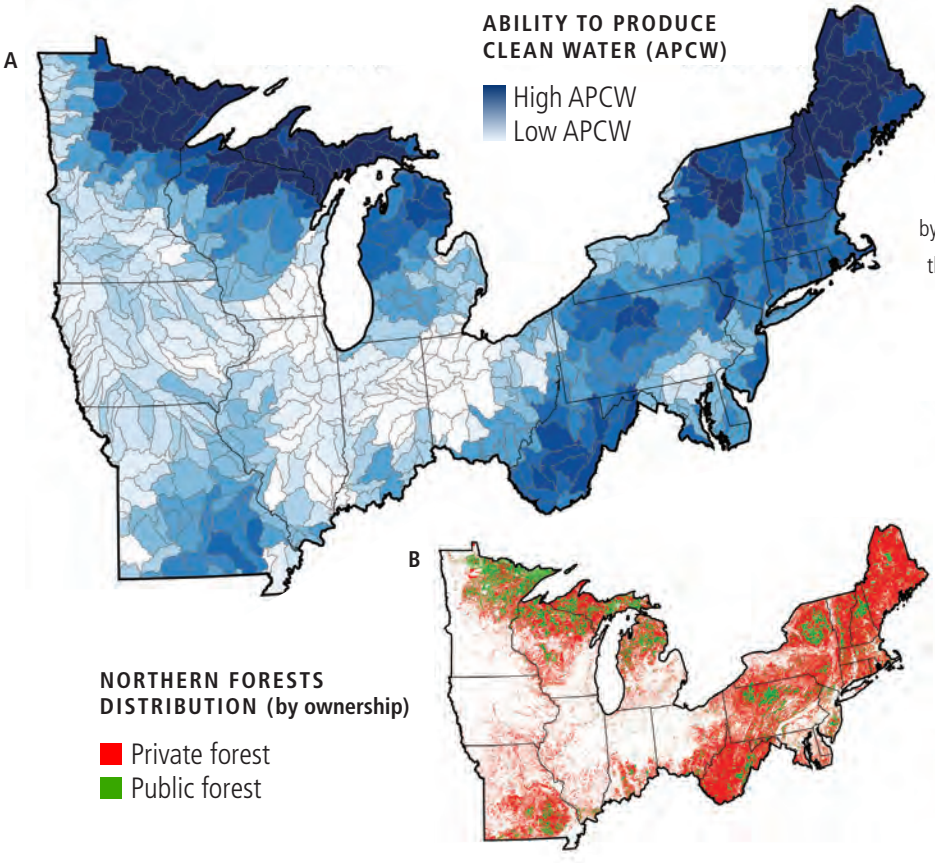


FIGURE 35

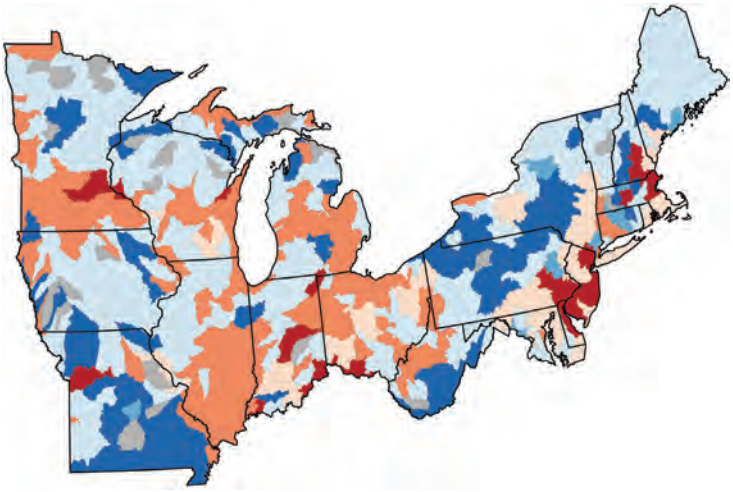
(A) Relative ability of 540 northern watersheds to produce clean water, represented by an index of water quality and watershed integrity that characterizes the biophysical condition of each watershed (Barnes et al. 2009, Homer et al. 2004, Protected Areas Center 2010); and (B) forest cover and ownership.

15 percent experienced better water quality with low vulnerability. Only 1.5 percent of the watersheds experienced better water conditions with high vulnerability. About 3 percent experienced less serious water quality problems with high vulnerability, and about 2 percent experienced more serious water quality problems with high vulnerability. Therefore, as the map illustrates, large areas of the northern watersheds may have potential water quality (as well as supply) problems. Some potential problem areas are in southern Illinois, Michigan, Minnesota, Indiana, New Hampshire; and Delaware, New Jersey, and Ohio.

One in 15 U.S. watersheds is highly vulnerable to further degradation (US EPA 2002). The following national indicators are similar to those of northern watersheds:

- Fifteen percent have relatively good water quality
- Thirty-six percent have moderate water quality problems
- Twenty-two percent have more serious water quality problems
- Twenty-seven percent do not have enough information to be characterized

The future abundance and quality of water supplies will not be ensured by a focus on water treatment alone. Protecting and managing forests in source watersheds is essential for providing clean, safe water (Barnes et al. 2009).



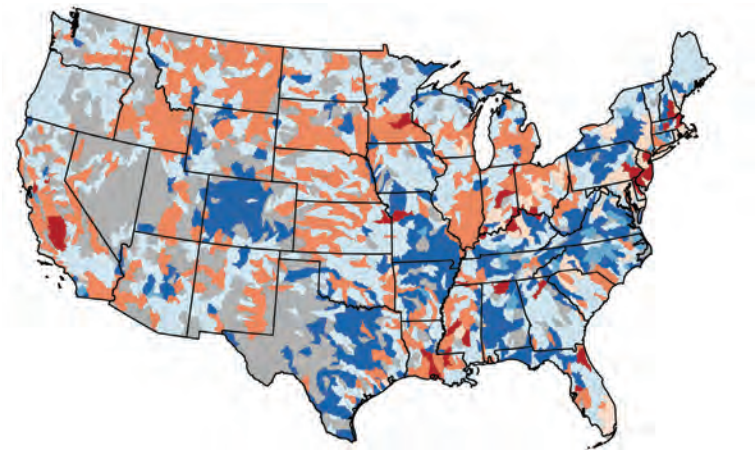


FIGURE 36

Watershed characterization—condition, vulnerability, and data sufficiency—in 1999 for (A) Northern States and (B) conterminous United States. Note that the strength of monitoring programs vary—areas with strong monitoring programs may show more problems than those with weaker programs (US EPA 2011).

NATIONAL WATERSHED CHARACTERIZATION - 1999

- More serious water quality problems - high vulnerability
- More serious water quality problems - low vulnerability
- Less serious water quality problems - high vulnerability
- Less serious water quality problems - low vulnerability
- Better water quality problems - high vulnerability
- Better water quality problems - low vulnerability
- Insufficient data

Criterion 5:

MAINTENANCE OF FOREST CONTRIBUTIONS TO GLOBAL CARBON CYCLES

Montréal Process Criterion 5 (Montréal Process Working Group 2010); Northern Area Forest Sustainability Indicators 11.1, 11.2, 11.3, 11.4 (USDA FS 2010d)

The importance of forest contributions to global carbon cycles

Northern forests cover more than 42 percent of the region and are enormous reservoirs of carbon. Through photosynthesis, live trees emit oxygen in exchange for carbon dioxide they pull from the atmosphere. As a tree grows it stores carbon in wood above and below ground, and sequestered carbon comprises about half of its dry weight. Dead trees and down logs are also reservoirs of carbon. Forest soils sequester additional carbon in the form of incorporated organic matter. In temperate northern forest ecosystems, roughly as much carbon is sequestered in forest soils as is sequestered as live biomass. Forests that are converted to other land uses release the carbon stored in the trees. Trees growing in newly established forests (afforestation) can sequester additional carbon.

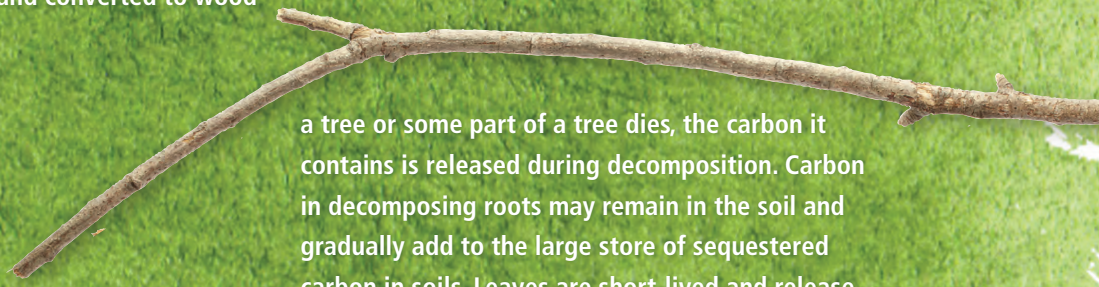
People and forests are closely linked through the carbon cycle. Human activities emit huge amounts of carbon dioxide during energy production, transportation, and other activities. Increases in atmospheric carbon dioxide have been linked to global warming. Because of their great extent and their capacity to sequester additional carbon or release carbon that is already sequestered, forests have an important role as sinks or sources of carbon in regional and global carbon cycles.

Global climate change associated with changes in atmospheric carbon dioxide levels could significantly impact the future conditions of forests, which would in turn affect the plants, wildlife, and people that depend on them. Maintenance of forest biodiversity and health are associated concerns.

Some forest management activities can increase carbon sequestration or offset human activities that emit carbon. Silvicultural practices that increase forest growth can increase the quantity of carbon sequestered in woody biomass. Wood product utilization can increase the quantity of carbon sequestered in durable wood products. Wood-based energy production can offset carbon that would otherwise be released by burning fossil fuels provided the carbon released during woody bioenergy production is reincorporated into new trees that replace those harvested for bioenergy. In contrast, energy generated from fossil fuels, such as coal and oil, emits carbon that has been sequestered underground for eons.

Key Findings for Criterion 5

- 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.
- 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.
- 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.
- 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.



Carbon and Wood

A cubic foot of wood in a living oak tree weighs about 60 pounds (green weight)—roughly half composed of water and the other half composed of dry woody biomass, about 15 pounds of which is carbon (half of the dry weight or a quarter of the green weight). Carbon is found in cellulose, hemicellulose, lignin, and other compounds that form the wood and other parts of the tree. Woody biomass may be reported in dry tons or in green tons, and carbon is more often reported as equivalent tons of carbon dioxide than as elemental carbon—distinctions that are important when interpreting and comparing biomass and carbon statistics.

When trees grow they absorb carbon from the atmosphere in the form of carbon dioxide. Through photosynthesis trees sequester the carbon in wood, bark, leaves, flowers, roots, and seeds. When a tree or some part of a tree dies, the carbon it contains is released during decomposition. Carbon in decomposing roots may remain in the soil and gradually add to the large store of sequestered carbon in soils. Leaves are short-lived and release carbon back to the atmosphere quickly as they decompose. Carbon may be sequestered for centuries in the wood of living trees. Large dead and down trees may sequester carbon for decades as they decompose slowly and gradually release carbon dioxide back to the atmosphere.

Each year, per capita emissions in the United States—largely due to combustion of fossil fuels—produce 6 tons of carbon or the equivalent of 22 tons of carbon dioxide (USDOE 2009, USDA FS 2011e). That is the amount of carbon in about 800 cubic feet of wood (roughly 10 cords). Stacked as firewood it would equal a wood pile 4 feet high, 4 feet deep, and 80 feet long.

The amount of carbon that U.S. forests sequester each year is about 10 percent of total annual U.S. emissions of carbon dioxide and related greenhouse gasses.

The passages below report on the total quantity of carbon stored in forests, how forest carbon changes over time, the role of forest products in carbon sequestration, and the capacity to avoid carbon emissions from fossil fuels by using woody biomass for energy production. For consistency with other sections of this assessment, we report carbon in U.S. tons (2000 pounds) and acres or provide metric equivalencies to help link reported values to other sources, which—by convention—report carbon in metric units (2204 pounds or 1000 kg) and hectares (2.5 acres).

Indicators of forest contributions to global carbon cycles for northern forests

Carbon sequestered in northern forests

The two largest pools of sequestered carbon in a typical forest are in soil organic matter and in aboveground biomass (Fig. 37). Soil carbon changes slowly compared to aboveground biomass, which increases with forest growth and decreases with mortality or harvesting. Dead wood, litter on the forest floor, and tree roots are other large reservoirs of forest carbon.

The amount of carbon sequestered above ground in a forest is closely associated with wood volume or biomass. In general, more sequestered carbon occurs where more wood volume occurs (Fig. 19). However, inventorying carbon is more complicated than merely measuring aboveground forest volume because of the high proportion of carbon in soils, tree roots, and dead wood and because harvested forest products move sequestered carbon to other locations.

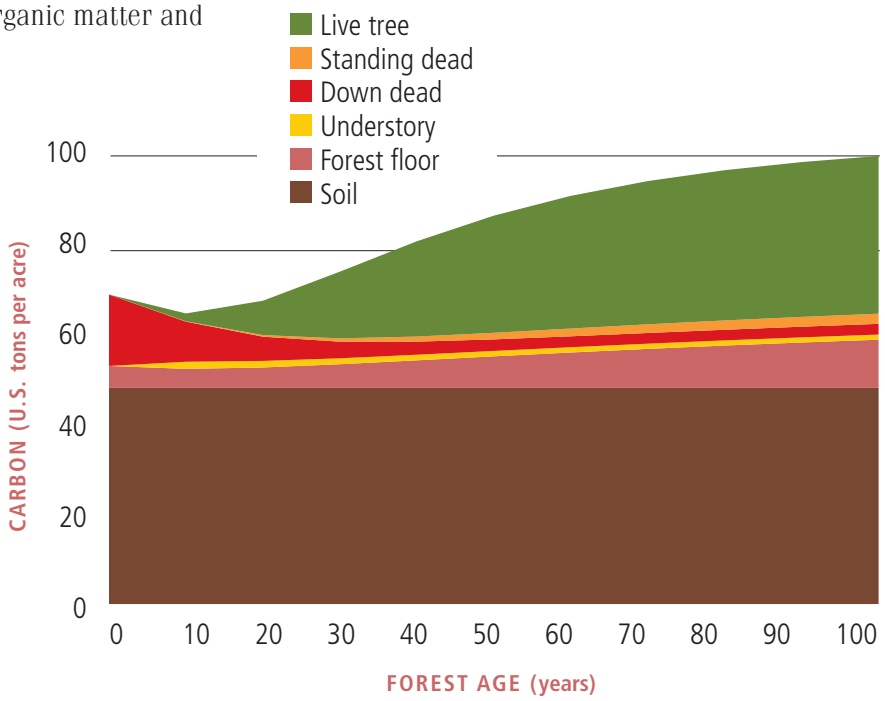
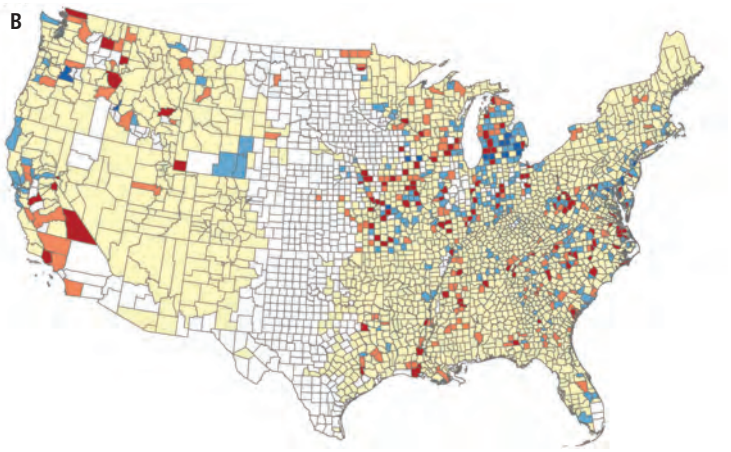


FIGURE 37

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).

Much of the carbon sequestered in U.S. forests is in Northern States (Fig. 38). This amount can increase over time as trees grow (above and below ground) and hold more carbon, or decrease as trees die or are harvested. As dead trees and down wood slowly decay, they release carbon gradually back into the atmosphere as carbon dioxide; if burned, they release carbon quickly. The total amount of sequestered carbon in U.S. forests is equivalent to about 27 years of carbon dioxide emissions for the United States (USDA FS 2011e). The annual increase in sequestered U.S. carbon from net annual forest growth is about 10 percent of U.S. annual greenhouse-gas emissions. Appendix Table A3 provides additional state-level detail on forest biomass and carbon.



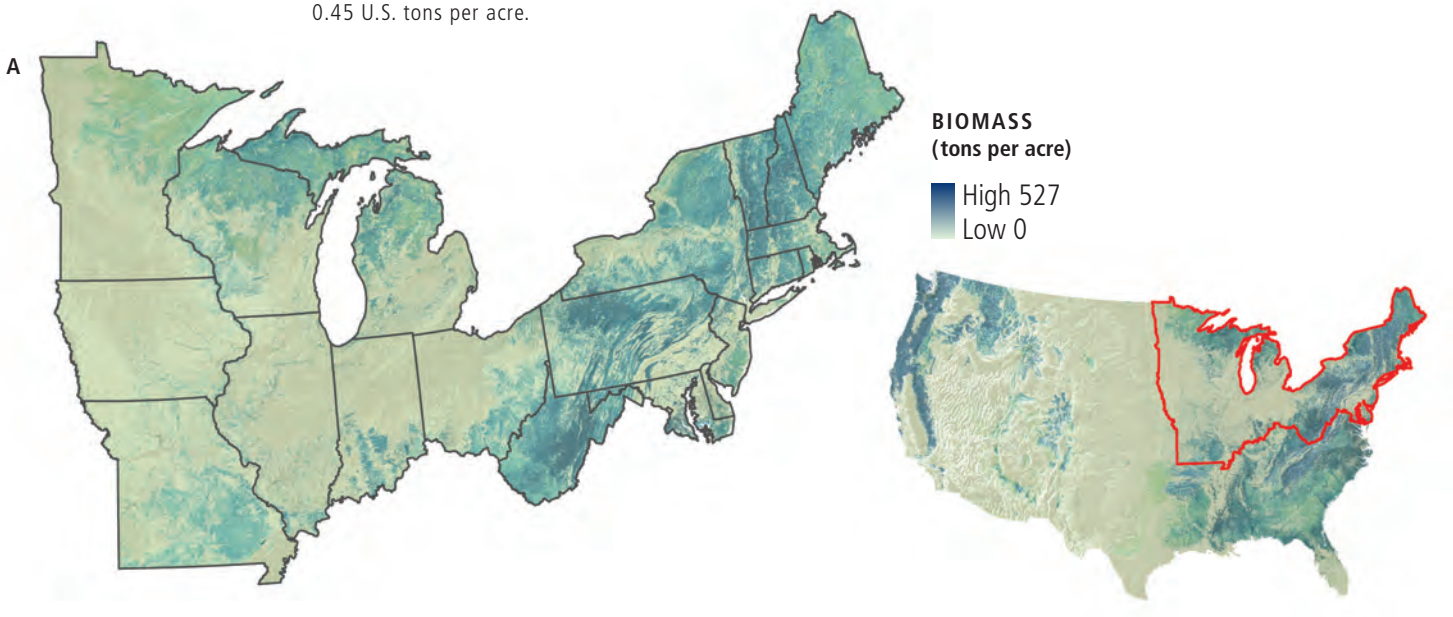


FIGURE 38

In 2006, (A) aboveground live tree biomass for Northern States (Blackard et al. 2008), and (B) estimated change in live tree carbon stock by U.S. county, accounting for harvest, land-use change and changes in live tree biomass of coarse roots, stems, branches, and foliage (Smith et al. 2009). In this case carbon change is reported as the equivalent mass in tons of carbon dioxide (CO_2) rather than carbon per se. One megagram (or metric ton) per hectare is equivalent 0.45 U.S. tons per acre.

Carbon Sequestered in Forest Products

When trees are harvested and converted to wood products, the carbon in those products remains sequestered until they decompose or are burned. Consequently, paper products typically sequester carbon for shorter periods than wood products such as building materials, flooring, or furniture. Even landfills sequester carbon in the form of discarded wood and paper products that decompose slowly because of compaction and lack of oxygen in the layers of landfill waste material. With the current mix of harvested materials and associate forest products, carbon in wood products from northern forests persists for a relatively long time.

Using Woody Biomass for Energy

The use of fossil fuels to produce energy releases carbon dioxide that was previously sequestered underground as coal, oil, or gas. By using woody biomass instead, society can reduce carbon from fossil fuels. Carbon that is already sequestered in the ground stays there (Malmsheimer et al. 2008) while carbon in woody biomass that is consumed for energy is released to the atmosphere instead. When forests harvested for biomass regenerate and grow, carbon is again sequestered in the wood growing on the regenerated forest. Thus, some carbon from using biomass for energy is cycled from the forest to the atmosphere and gradually back to the forest.

In 2007, about 2 percent of all U.S. energy consumption came from wood combustion by industrial (1.3 percent), residential (0.4 percent), utility (0.2 percent), and other (0.1 percent) users. Electric utilities throughout the North use wood for part of their energy production (Fig. 39), but less than 1 percent of U.S. electric power is generated with wood (USDOE EIA 2010).

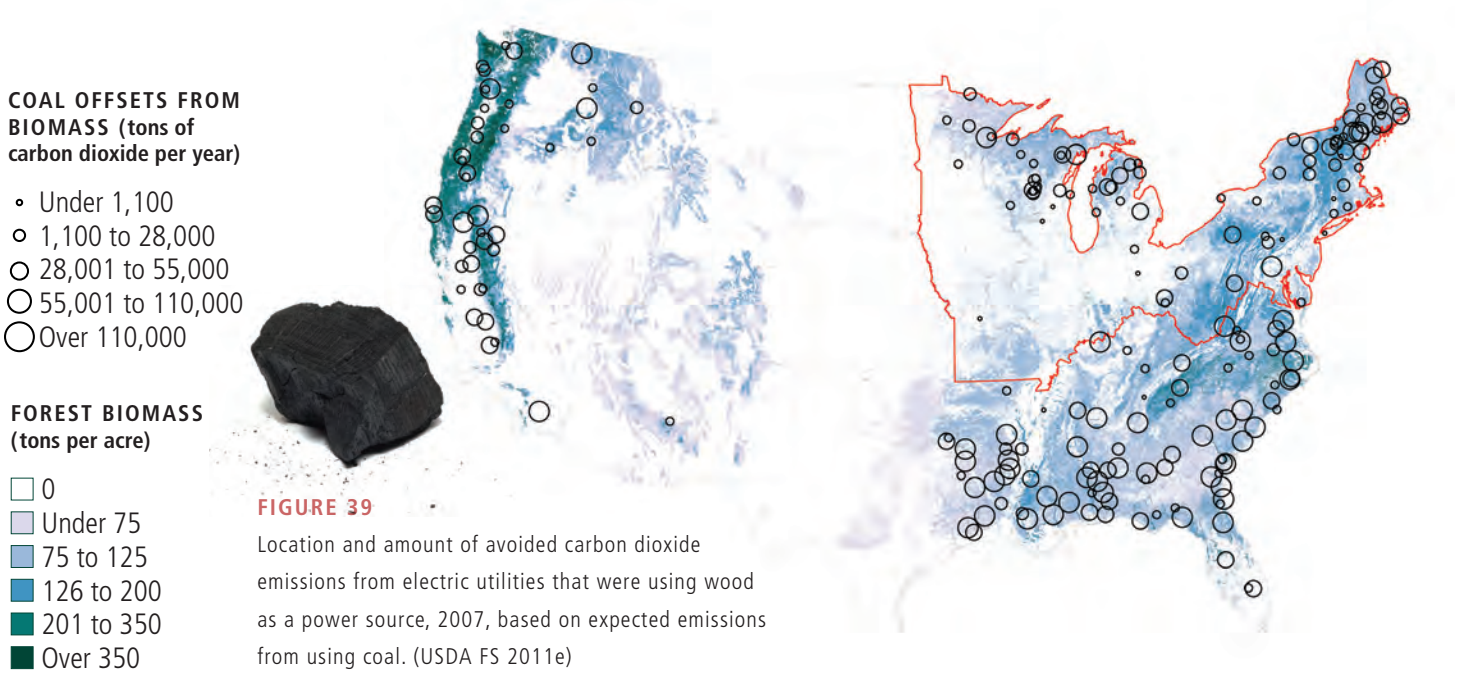


FIGURE 39

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)

Criterion 6:

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

Montréal Process Criterion 6 (Montréal Process Working Group 2010); Northern Area Forest Sustainability Indicators 12.1-12.5, 13.1-13.6, 14.1-14.5, 15.1–15.6, 16.1–16.5 (USDA FS 2010d)

The importance of long-term multiple socioeconomic benefits from forests

Forests provide an array of products and services that maintain and enhance benefits to our society and economy. Benefits derived from forests may be categorized into wood products, nontimber products and services, and ecosystem services. The value and volume of these products and services indicate the importance of forests for a wide variety of uses. Tracking

Key Findings for Criterion 6

- 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.
- Northern forests are a major source of wood products, but imports are expected to continue to supply a sizeable amount that is consumed.
- The largest forest products groups are hardwood, saw logs, and pulpwood.
- 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).
- The North is the source of nearly all U.S. commercial maple syrup production.
- The most common nature-based recreational activities in northern forests are walking for pleasure; family gatherings; viewing/photographing scenery, wildlife, flowers; picnicking; sightseeing; and driving for pleasure.

values, volumes, and employment through the production process—from the forest to the end of secondary processing or other utilization—explains a key dimension of the socioeconomic contributions that forests make to local, regional, and national economies.

A holistic evaluation of the socioeconomic benefits from forests necessarily includes contributions from ecosystem services as well as market values for wood and nontimber products. In the absence of working markets, the value of ecosystem services can be difficult to quantify. Nevertheless, previous sections present detailed qualitative information about key ecosystem services such as carbon sequestration, watershed protection, and sustaining biological diversity. The following section gives greater—but not exclusive—attention to products and services that can be quantified through actual markets, payments to landowners, or other estimates of value. For example, forest-based and forest-related employment is a tangible and widely understood measure of economic and social well-being. Similarly, declining on-the-job injury rates reflect improved employment quality, which provides personal and community benefits.

The indicators reported here summarize the best available data to report revenues or economic activity associated with producing (or consuming) important commodities and ecosystem services, but may not be full measures of all the values that forests supply to society. Many such values are not reflected in market transactions, and market prices fail to fully capture the total contribution of forests to human well-being. The value of ecosystem services from urban and community forests is addressed in detail in subsequent sections.

Indicators of socioeconomic benefits from northern forests

Consumption of wood and wood products

Consumption of wood and wood products reflects the importance of forests as a source of raw materials. Comparison of consumption and production of wood and wood products illustrates the balance (or lack) between supply and demand. Most timber harvesting in the United States is in response to demand for the wood products that people use in their daily lives.

Total U.S. consumption of timber products including wood products, paper products, and fuelwood was 21 billion cubic feet in 2005 (Fig. 40), equivalent to 71 cubic feet of wood per person (Fig. 41) (also see The Wood You Consume, page 5). Over the past 40 years, per capita annual consumption has ranged from 67 to 83 cubic feet, gradually decreasing since 1987. However, because of population growth, total U.S. consumption of wood products over the past 40 years increased from 13 to 21 billion cubic feet. Consumption statistics are not commonly disaggregated below the national level, so we have assumed that the North consumes about 42 percent of the Nation's timber products because it has about 42 percent of the Nation's population.

Socioeconomic Benefits of Forests

The economic value placed on forests reflects the benefit that society derives from them, as indicated by the prices paid for marketed goods and the values estimated, often by indirect measures, for nonmarketed goods. For example, the value of timber products is partly given by the price of those goods in the market. Conversely, the value of recreation on public forest lands is not easily measured in dollars spent, but surveying recreationists can provide measures of willingness to pay. Observing time and money invested for traveling to and from a recreation site can provide travel-cost estimates. In addition, many people seek the scenic views, privacy, and quiet that come from living near a park or natural area, especially in crowded urban settings; the value of these areas can be estimated by determining the premium paid for adjacent lots. Using such methods can help to account for the many values forests have for society.

Economists often classify the value of forests in the following categories (Pearce 2001):

- DIRECT USE VALUES—Values from the consumptive and nonconsumptive uses of products and services such as timber, fuelwood, tree sap, or recreation.
- INDIRECT USE VALUES—Values from various forest services, such watershed protection, storage of carbon, and provision of wildlife habitat.
- OPTION VALUES—Values from desiring to conserve the option for future use even though not taking advantage of current availability; for example, although many individuals may not visit some forests, they value knowing that they could one day enjoy them.
- NON-USE VALUES—Values from individuals supporting forest conservation and sustainability; unrelated to current or planned use of the forest, this is also known as existence or passive value.

FIGURE 40

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

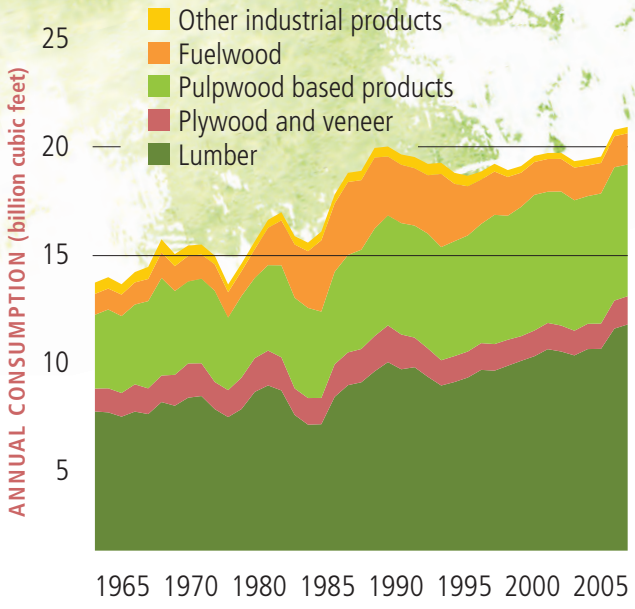
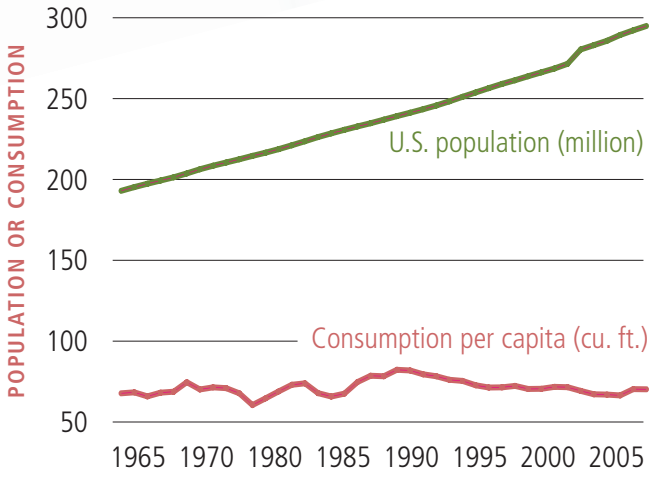


FIGURE 41

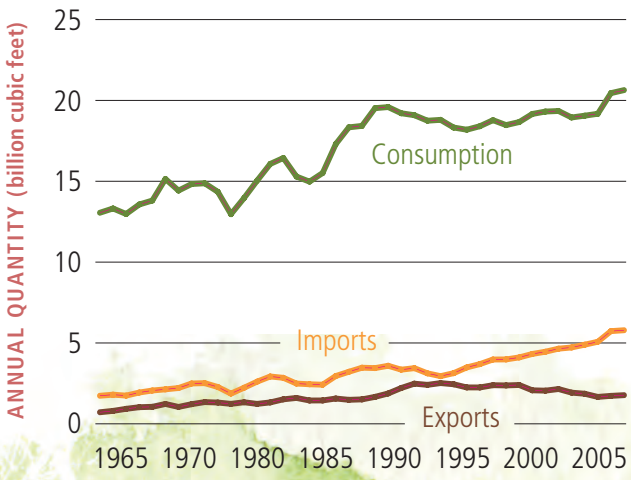
U.S. population and per capita consumption of timber products including wood products, paper products, and fuelwood (Howard 2007, U.S. Census Bureau 2009).



U.S. consumption of timber products is met by a combination of domestic production and net imports (imports in excess of exports). With increased population growth and consumption, imports have increased to supply a greater share of the U.S. wood products market. In 2005, 20 percent of total U.S. wood consumption was from imports (Fig. 42).

FIGURE 42

Total U.S. consumption, imports, and exports of timber products (Howard 2007).



Assessing the Direct Value of Wood Product Manufacturing with the North American Industry Classification System

Information on U.S. product manufacturing is maintained by the U.S. Census Bureau, which classifies wood products under North American Industry Codes (NAICS) 113, 321, 322 and 337.

NAICS 113 industries are involved in growing, cutting, and transporting timber; and in producing wood chips in the field. This includes traditional forestry and logging operations. Because production cycles for NAICS 113 establishments are 10 years or more, Christmas trees and other short-rotation products are classified as crop production, and not included in NAICS 113.

NAICS 321 includes establishments that manufacture wood products such as lumber, plywood, veneers, wood containers, wood flooring, wood trusses, manufactured or mobile homes, and prefabricated wood buildings. NAICS 322 includes industries that make pulp, paper, or converted paper products. Converted paper products include stationary, paperboard, bags, boxes, and other items manufactured from pulp and paper. Together, NAICS 321 and 322 comprise information for the primary wood products manufacturing sector.

NAICS 337 includes manufacturers of furniture and related products such as mattresses, window blinds, cabinets, and fixtures. NAICS 337 captures some of the activity in the secondary wood products manufacturing sector, but does not differentiate wood-based products from other products. Consequently, we exclude information from NCAIS 337.

Value and volume of wood and wood products production

The value of wood products produced by the wood products industry (North American Industry Classification - NAICS 321) and the pulp and paper industry (NAICS 322) was estimated at $281 billion nationally and $112 billion (40 percent) for the Northern States in 2006. Added value of primary wood products manufacturing—calculated by subtracting the cost of manufacturing from the value of shipments—was $124 billion nationally and $52 billion (41 percent) for Northern States.

Table 9 shows the volume of roundwood processed by product categories for Northern States. Roundwood is a term used to represent logs, bolts, or other round sections cut from trees for industrial or consumer use, either in the original round form (such as transmission poles or pilings) or as raw material to be manufactured into sawn wood, panel products, paper, or other industrial products (Stokes et al. 1989, Food and Agriculture Organization 2010).

Northern States produced 3.0 billion cubic feet of roundwood in 2007, 2.3 billion (76 percent) from hardwoods and 0.7 billion from softwoods (Fig. 43). The region's primary roundwood products are hardwood saw logs, pulpwood, and fuelwood. Saw logs are logs whose size and quality meet regional standards to be sawn into boards. Pulpwood is roundwood used as a source of wood fiber in a pulp mill. Fuelwood is

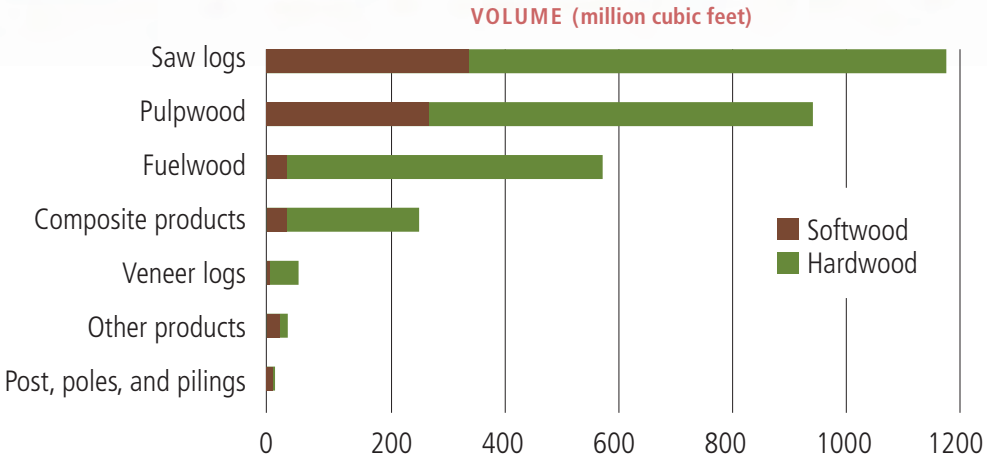


FIGURE 43
Volume of roundwood products by end use in the Northern States, 2007, based on U.S. Forest Service timber product output reports (USDA FS 2011i).

Table 9—Volume of roundwood products by State and type of products, 2006, sorted from most to least total roundwood production (USDA FS 2011i).

State and region	Total roundwood products	Saw logs	Veneer logs	Pulp-wood	Composite products[a]	Posts, poles, and pilings	Fuel-wood	Other products
	(million cubic feet)							
Maine	563	203		239			121	
Wisconsin	414	100	6	219	43	2	38	7
Michigan	373	128	8	135	66	4	30	2
Minnesota	326	48	1	124	113	<1	39	<1
New York	243	82	4	76	3	<1	77	<1
Pennsylvania	223	119	19	64		1	6	13
Missouri	166	113	1	7		1	36	7
West Virginia	164	104	10	6	35	2	5	1
Indiana	108	68	3	2		<1	34	1
Illinois	96	35	1	1		<1	56	3
Ohio	76	48	<1	24			4	1
Vermont	61	33		10			18	
Maryland	60	28		11			20	
Massachusetts	50	7		1			41	<1
New Hampshire	42	25	1	11			5	<1
Iowa	26	15	1			<1	10	<1
New Jersey	26	1		<1		<1	25	
Connecticut	13	5		<1			7	
Delaware	9	4		5			<1	
Rhode Island	5	1					3	
North total	3,045	1,168	56	938	261	12	576	35
U.S. total	14,990	7,179	1,211	4,394	544	100	1,408	155
North as percent of U.S. total	20	16	5	21	48	12	41	23

[a]*Many of the products in the composites category are made from logs in the pulpwood size class.*

wood mill residues, cull logs, and branches used to fuel fires in a boiler or furnace (Stokes et al. 1989). Other products from Northern States are wood composites including particle board, oriented strand board, and other engineered wood products made using adhesives; logs sliced for veneer; and fence posts, utility poles, and pilings. Only a small portion of roundwood is manufactured into composite products, even though during manufacturing they can deliver greater added value per unit of wood than saw logs, pulpwood, or fuelwood.

Production of wood products in the North has fluctuated over time (Fig. 44). Total roundwood production peaked in the late 1980s, driven primarily by increased harvesting for fuelwood, saw logs, pulpwood, and composites. Saw log harvesting peaked in 1996, driven by increased standing inventory (especially select oak species and hard maples), demand from the kitchen-cabinet and pallet industries, and exports (Luppold and Bumgardner 2008). Since then, lumber production and harvesting of saw logs have stagnated because of increasing pressure from low-cost imports of finished products. Growth in production in the region appears to be driven by smaller manufacturers producing more customized products (Luppold and Bumgardner 2008). Although northern roundwood production includes 15 major species groups, about two-thirds is from oaks, aspens, maples, spruce, and pines (Fig. 45).

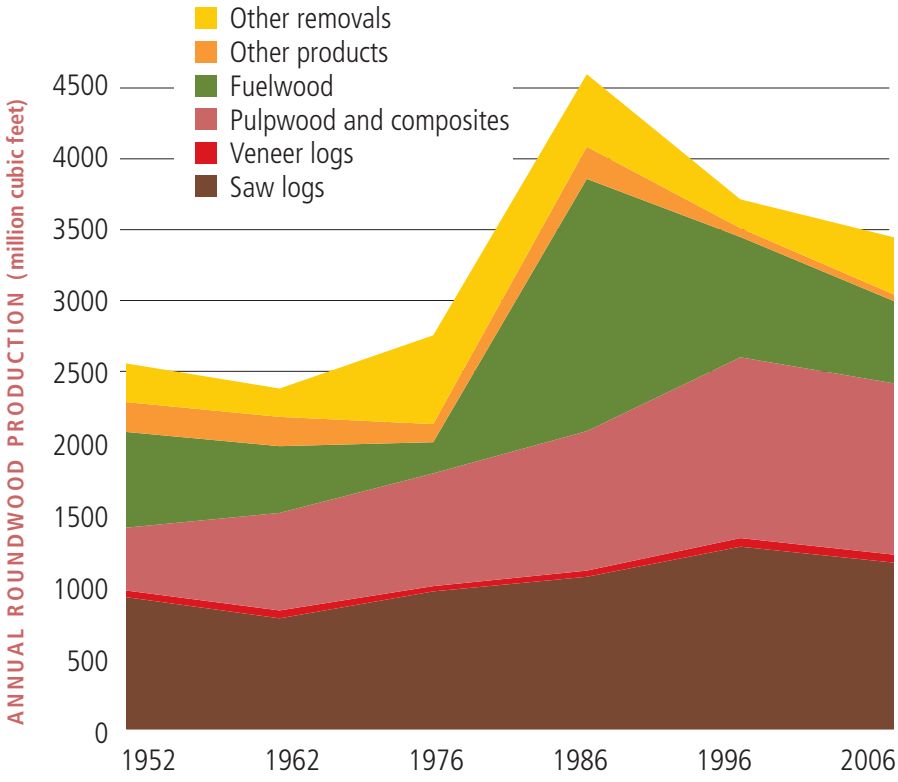
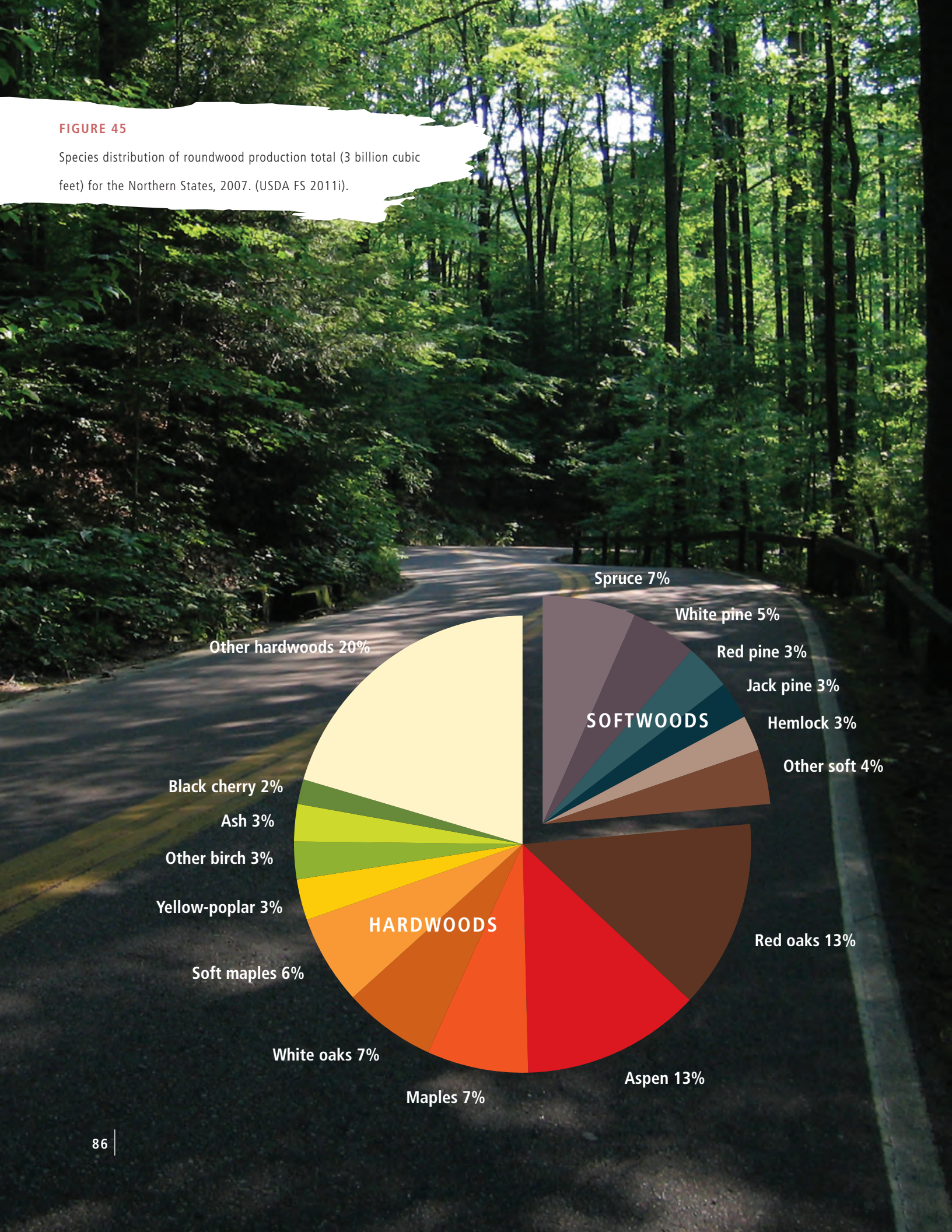


FIGURE 44
Production of roundwood products in the Northern States, 1952 to 2006 (Smith et al. 2009).

FIGURE 45

Species distribution of roundwood production total (3 billion cubic feet) for the Northern States, 2007. (USDA FS 2011i).



Recovery or recycling of wood products

Recovery and recycling wood products allows a country or region to maintain or increase consumption without harvesting more trees. Increased recovery and recycling can help reduce environmental impacts associated with harvesting, transporting, and processing trees and can reduce the quantity of materials sent to landfills. The recovery rate is the quantity of material recovered and recycled divided by the amount of sourced product. A high annual recovery rate implies high efficiency in using resources, an important step toward achieving forest sustainability.

Pulp and paper product recovery has become an important activity in Northern States, with both the recovered amount and the recovery rate increasing substantially since the 1970s. From 1976 to 2004, the amount of recovered paper nearly doubled (from 8.7 to 16.4 million tons), mirroring national trends (Fig. 46). Data from the Paper Industry Association Council (2009) indicate that northern access to curbside recycling was higher than the national average.

Recycling is also common for other wood products. Most residues from the U.S. wood products manufacturing process are converted into fuel or engineered wood products (Ince 1996). Recovery of shipping pallets is a widely adopted and financially sound practice. More than 1,000 U.S. firms are in the business of pallet recycling (Recycler's World 2009). As a result of increased efforts toward recycling, less than 1 percent of pallets are landfilled each year (Bush et al. 2007).

Nontimber forest products

In 2007, nontimber forest product sales in the United States had an estimated retail value of $1.4 billion or about $4.50 per capita. Edibles, decorative materials, medicinal plants, cultural items, and landscaping materials amounted to

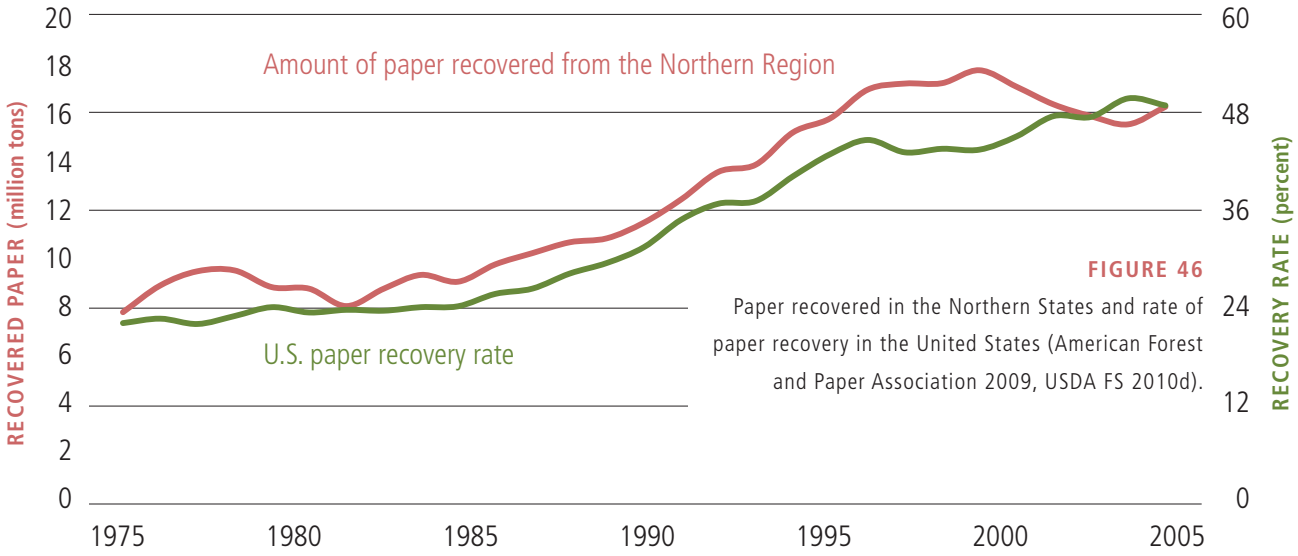


FIGURE 46

Paper recovered in the Northern States and rate of paper recovery in the United States (American Forest and Paper Association 2009, USDA FS 2010d).

roughly $468 million of that total (Alexander et al. 2011, USDA Forest Service 2011e). The remainder was primarily wood products such as firewood or fence posts gathered and sold in small quantities for personal use. National data on nontimber forest products are limited to national forest receipts for permits and small contracts; the dollar estimates presented above are based on collection permits issued for Federal lands that were extrapolated to private forest land lands. Consequently, the estimates are subject to considerable variation and best suited to estimating the relative rankings among product categories rather than the actual dollar value.

Most northern forest land is privately owned. The best available information on collection of nontimber forest products from private forest land comes from voluntary reporting through the National Woodland Owners Survey (USDA FS 2009b). For most States, the most common products collected on private forests are edibles and decorative or medicinal plants (Table 10).

Nontimber Forest Products

Nontimber forest products include edibles (such as nuts, berries, mushrooms, and maple sap), decorative materials (such as floral items, boughs, cones, vines, moss, and lichens), medicinal plants (such as ginseng), cultural items (materials for traditional or ceremonial activities), landscaping materials (such as transplants, rocks, and gravel), and wood products gathered and sold in small quantities (such as wild-grown Christmas trees, residential fuelwood, and fence posts). Gathering nontimber forest products on Federal land is monitored through permits or small contracts, and those can be used to estimate the following national ranking of nontimber forest products which is ordered by greatest to least dollar value of harvested material (USDA FS 2009a).

1. Residential fuelwood
2. Floral/craft items
3. Wild-grown Christmas trees
4. Edibles
5. Landscaping materials
6. Posts and poles
7. Grass/forage
8. Seeds and cones
9. Herbs and medicinal plants

Other rankings of nontimber forest products in the North were compiled from an open-ended survey of National Forest managers who listed the relative importance of each product. Medicinal plants (presumably due to ginseng gathering) rank far higher in this survey than in the national rankings. (McLain and Jones 2005).

1. Residential fuelwood
2. Christmas trees
3. Medicinal plants
4. Mushrooms; tree boughs
5. Sap; Other plants
6. Edible plants; floral greens; moss; rocks, sand, or gravel; posts or poles; transplants
7. Bark
8. Seeds; craft wood; construction wood

Table 10—Collection of nontimber products reported by family forest landowners by State and product category, and forest land acres involved (based on the total area of the forest ownership where the activity occurred). Because products are not mutually exclusive, owners can be tallied in multiple categories and percents cannot be summed across categories (USDA FS 2009b).

State and region	Edibles	Decoratives	Medicinals	Cultural items	Edibles	Decoratives	Medicinals	Cultural items
	(percent of owners)				(percent of acres)			
Vermont	39	20	3	<1	22	11	4	1
Missouri	20	5	3	<1	21	8	4	<1
Iowa	18	16	1		22	5	4	
Wisconsin	18	8	1	1	20	10	2	1
Illinois	15	3	2		21	7	5	
Ohio	15	14	5	1	17	12	9	<1
Minnesota	13	8	<1	<1	14	9	1	1
Michigan	13	7	1	1	14	7	1	1
Maine	13	5	<1	<1	6	6	1	<1
Indiana	12	9	<1	1	16	9	4	1
New York	12	6	2		13	6	1	
Connecticut	11	12			5	5		
Massachusetts	11	5	2		13	10	2	
Rhode Island	11	5		5	10	10		3
New Hampshire	9	33	1	<1	14	10	1	1
Pennsylvania	7	7	2	<1	10	5	2	<1
Maryland	7	4			10	5		
West Virginia	6	2	3	<1	9	4	3	<1
Delaware[a]	--	--	--	--	--	--	--	--
New Jersey[a]	--	--	--	--	--	--	--	--
Northern total	12	8	2	<1	13	7	2	<1
Total number of owners participating (1,000)	613	386	85	14				
Total acres included (1,000)					17,182	9,020	2,932	428

[a]*Not reported separately by state*

On northern private forest land in aggregate, more than 613,000 owners (one in eight) collect nontimber products.

The value of nontimber forest products sold via permits on northern National Forests was estimated at $175,000 in 2007 (Table 11).

More than half of total revenues were from residential fuelwood, followed by evergreen limbs and boughs for decoration, fence posts, and wild-grown Christmas trees (only 2,000 wild-harvested Christmas trees, in contrast to the annual harvest of 5.7 million Christmas trees from plantations).

Table 11—Estimated proportion and value of nontimber products harvested from National Forests in the Northern United States via permits, 2007. Note that missing entries indicate no reported sales (Personal communication from Susan Alexander, U.S. Forest Service, 13 October 2009).

Product	Proportion of nontimber sales	All National Forests	Wisconsin	Missouri	Michigan	Pennsylvania	West Virginia	Minnesota	New Hampshire	Vermont	Ohio	Illinois	New York	Indiana
	(%)	(U.S. dollars)												
Fuelwood	55	97,178	29,207	9,279	18,352	17,075	11,313	1,470	5,250	2,180	1,500	1,020	520	13
Limbs & boughs	17	29,083	15,993		8,850		120	4,020		100				
Posts	17	29,073		29,013				60						
Christmas trees	6	10,270	4,235		1,320		70	2,045	1,540	1,060				
Grass	2	3,296	30	2,646				180			440			
Tree sap	2	2,826			110			1,706	1,010					
Roots	1	1,560					440				1,120			
Mosses	< 1	660	520		140									
Other products	< 1	579	355		70			154						
Transplants	< 1	180	20					160						
Cones	< 1	140	140											
Bark	< 1	123						123						
Needles	< 1	68			68									
Other plants	< 1	60	40		20									
Foliage	< 1	40						40						
Mushrooms	< 1	20								20				
Total	100	175,156	50,540	40,938	28,930	17,075	11,943	9,958	7,800	3,360	3,060	1,020	520	13

Maple sap used in syrup production is an important product collected in northern forests. Commercial maple syrup production in large quantities is limited to 10 States, all of them in the North (Table 12). Total production for 2009 was 2.4 million gallons, with a value exceeding $91 million. In recent years both the value per gallon and the production of maple syrup have risen sharply (Fig. 47).

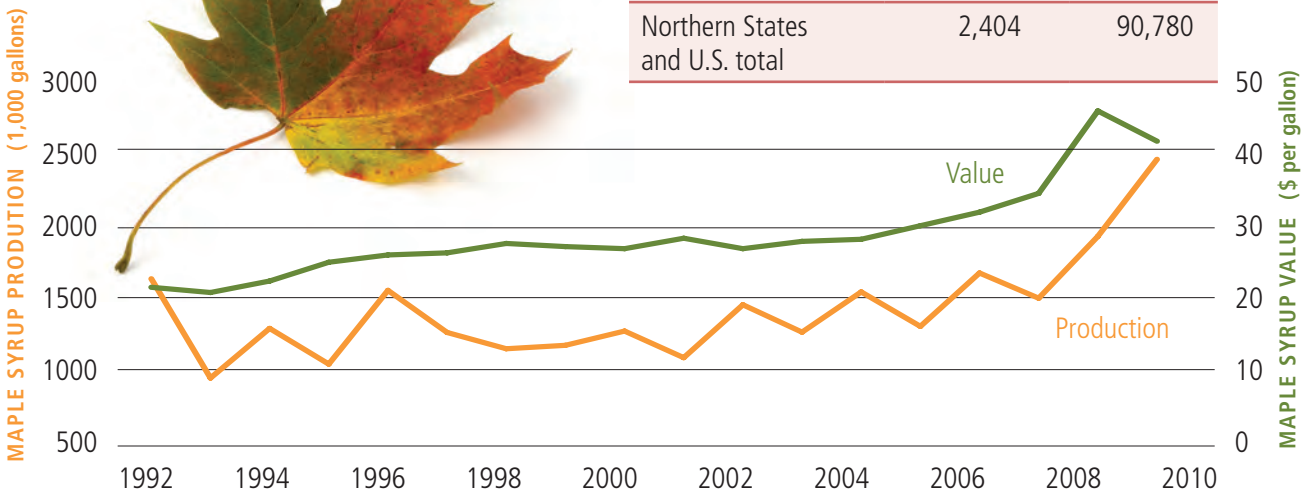
The total value of nontimber products consumed in the United States exceeds the value of nontimber products produced domestically, because the United States is a net importer of many nontimber products. For example, annual exports exceed $15 million each for foliage and branches, wild blueberries, mushrooms, and ginseng. However, annual imports exceed $30 million each for foliage and branches, wild blueberries, pine nuts, vanilla beans, and maple syrup (USDA FS 2011e).

Table 12—Maple syrup commercial production in the United States, 2009 (USDA NASS 2010). All reported commercial maple syrup production is in these 10 States.

State and region	Production	Value
	(1,000 gallons)	($1,000)
Connecticut	13	800
Massachusetts	46	2,466
Ohio	90	3,627
Pennsylvania	92	3,505
New Hampshire	94	4,756
Michigan	115	5,175
Wisconsin	200	7,340
Maine	395	12,996
New York	439	17,823
Vermont	920	32,292
Northern States and U.S. total	2,404	90,780

FIGURE 47

Maple syrup production and value, 1992 to 2009; note that virtually all U.S. commercial maple syrup production occurs in the Northern States (USDA NASS 2010).



Revenues from forest-based ecosystem services

Private and public markets are evolving to compensate forest landowners for the ecosystem services that their forests provide for the common good. Primarily voluntary markets have emerged to pay for services such as carbon sequestration, watershed protection, and preservation of sensitive forest lands. Future Federal and international regulations to facilitate payments for ecosystem services will be strongly influenced by the adoption or avoidance of mandatory compensation systems.

From 2003 to 2010, payments for carbon sequestration contracts were sold through the Chicago Climate Exchange in these categories: afforestation/reforestation, sustainably managed forests, and long-lived wood products. Landowners entered into contracts for 15 years or longer to sell future increases in the carbon stocks that were sequestered in their trees or wood products (Chicago Climate Exchange 2009). Absent mandatory carbon cap-and-trade legislation or similar restrictions on carbon emissions, the value of carbon credits in the United States has declined to the point where new U.S. carbon sequestration contracts are no longer being sold (Gronewold 2011), although sales continue in some international markets.

Forests can play an instrumental role in addressing climate change challenges. Management practices that avoid deforestation, increase afforestation, or increase net growth offer the greatest potential for carbon sequestration (Table 13). Additionally, using wood for energy—typically considered a commodity rather than an ecosystem service—provides an added benefit by reducing emissions from fossil fuels that would be used instead.

The important role that forests play in protecting watersheds can also result in revenues paid to landowners for maintaining

Table 13—Estimated carbon sequestration potential for selected U.S. land-use practices.

Activity	Carbon sequestration	Source
	(tons per acre per year)	
Avoided deforestation	92.3 to 189.7	U.S. Department of State (2000)
Afforestation (previously cropland/pasture)	2.4 to 10.5	Birdsey (1996)
Reforestation	1.2 to 8.5	Birdsey (1996)
Changes in forest management	2.3 to 3.4	Row (1996)
Riparian or conservation buffers (nonforest)	0.4 to 1.1	Lal et al. (1998)
Reduced/conservation tillage	0.7 to 1.1	West and Post (2002)
Grazing management	0.1 to 2.1	Follet et al. (2001)

tree cover. A well publicized example is the New York City Watershed Agreement (US EPA 1996), under which 9 million residents of New York City and surrounding suburbs rely on drinking water from reservoirs located miles away in the Catskill and Delaware watersheds. The Watershed Forestry Program was formally established as a voluntary pollution prevention partnership between New York City and the upstate New York forestry community in September 1997. The program provides cost sharing to landowners for the development of long-term forest management plans written with the help of professional foresters who are specially trained by the partnership. By April 2003, more than 290 management plans were completed covering more than 55,000 acres, of which 45,000 are forested. The project also includes a Best Management Practices component, logger training, and coordination of research, demonstration and education efforts (New York City Department of Environmental Protection 2009).

The Forest Legacy Program, administered by the Forest Service in partnership with individual States, is an example of a voluntary public program aimed at protecting environmentally sensitive forests on private lands (USDA FS 2009a, 2010c). Forest lands supply multiple benefits including timber products, wildlife habitat, soil and watershed protection, aesthetics, and recreational opportunities. When forests become fragmented and disappear, so do some of the benefits they provide. The Forest Legacy Program encourages and supports acquisition of land-protection agreements (legally binding agreements transferring a negotiated set of property rights from one party to another) without removing the property from private ownership. Most conservation agreements restrict development, require sustainable forestry practices, and protect water quality and other values. In 2009, 1.9 million acres nationally were enrolled in the Forest Legacy Program, of which 1.3 million acres (68 percent) were in Northern States—contributing to the extent of protected areas in the region. Forest Legacy Program goals in most States focus on maintaining water quality, wildlife habitat, and biodiversity (Table 14).

Table 14—Goals commonly identified by State Forest Legacy Programs and their frequency (USDA FS 2011e).

Goal	Number of States
Water quality, wetlands, and riparian buffers	37
Wildlife, habitat, biodiversity	35
Recreation	23
Threatened and endangered species	17

The U.S. Forest Service estimates that government and nongovernment payments for ecosystem services nationwide reached $553 million in 2007 (Table 15). Although this figure is not complete because data are unavailable for several States, the trend in payments from public and private sources (from nongovernmental organizations, for example) is increasing (USDA FS 2009a).

Table 15—Approximate total U.S. payments for environmental services from Federal and State agencies, nongovernment organizations, and individuals in constant 2005 dollars (USDA FS 2011e).

Program	Years		
	2005	2006	2007
	($ million)		
Government			
Federal programs	248	243	248
State programs	8	9	12
Nongovernment			
Voluntary carbon market	<1	<1	6
Conservation agreements	69	92	111
Fee simple purchases	142	177	177
Total payments			
	468	521	553

Investments and expenditures in forest management, industries, services, and research

Investment in forest management is needed to improve capacity of forests to produce wood and nonwood products and to increase ecosystem services. Research and development investments are required to improve forest management and manufacturing efficiency.

From 1997 to 2006, annual capital expenditures in wood products manufacturing in Northern States increased 46 percent, from $0.8 to $1.2 billion (Fig. 48). However, during that same period, capital expenditures in pulp and paper products manufacturing decreased 18 percent from $3.5 to $2.9 billion (U.S. Census Bureau 2009).

Most Federal investments in forest management in the North were allocated though Forest Service budgets, via Forest Service Region 9 (Eastern Region) for National Forest management or via Northeastern Area State and Private Forestry for forest management, planning, pest management, wildfire management, and other programs with the States. From 2005 to 2010 annual discretionary appropriations increased from $155 million to $160 million for Forest Service Region 9 and from $85 million to $95 million for State and Private Forestry (Fig. 49). In 2010, $42 million of those combined appropriations were allocated to wildfire management and $1 million to land acquisition.

State forestry programs are funded from multiple sources including State government, Federal government, and revenue from services and products. According to the National Association of State Foresters (2011), non-Federal funding for forests in the Northern States (total funding minus Federal funding, excluding missing data for Illinois and Ohio) was $396 million in 2008.

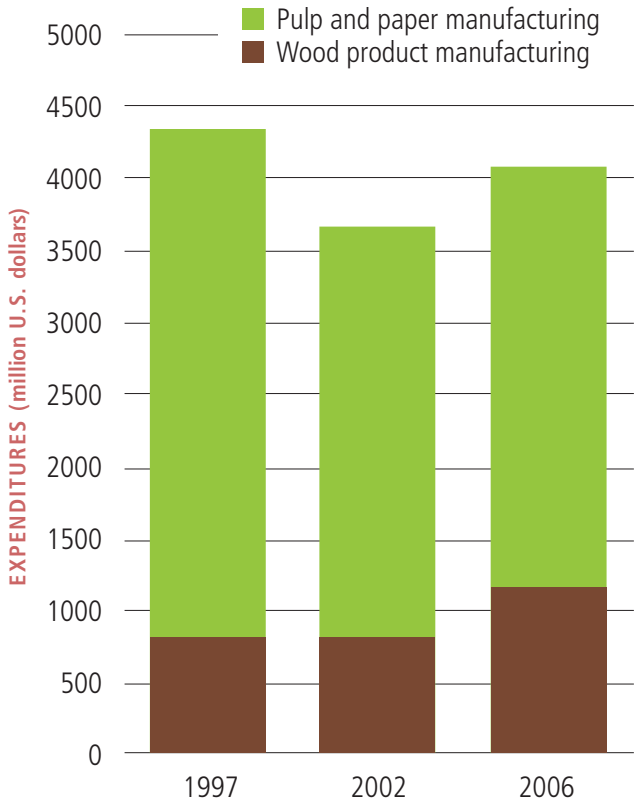


FIGURE 48

Capital expenditures in wood products (NAICS 321) and in pulp and paper (NAICS 322) manufacturing in the Northern States, 1997, 2002, and 2006 (U.S. Census Bureau 2009).

U.S. Forest Service discretionary research appropriations to the Northern Research Station, which serves the 20-State region, increased from $55 million in 2005 to $64 million in 2010 (Fig. 49), some of which went to cooperative research studies with universities. In 2006, forest research funding to universities in the North (all sources) was $95 million compared to $87 million for the South, $67 million for the Pacific Coast, and $40 million for the Interior West. State appropriations funded about half of forest-related research at northern universities, followed by Federal sources for about a third, and industry and other sources for the remainder. (USDA FS 2011e)

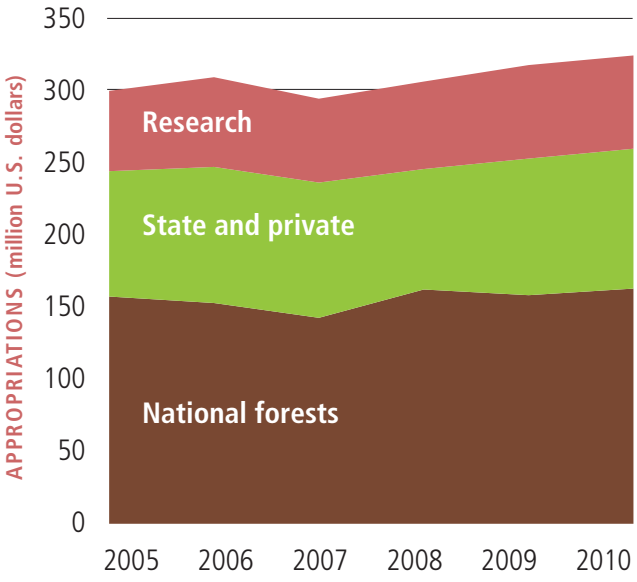


FIGURE 49

U.S. Forest Service discretionary appropriations by fiscal year within the Northern States for national forests in Forest Service Region 9, Northeastern Area State and Private Forestry, and the Northern Research Station.

Employment in the forest products sector

Nationwide, the forestry and logging wood products industries (excluding furniture) and the pulp and paper industries employed 1.1 million people in 2006 (U.S. Bureau of Labor Statistics 2007a). This included more than 72,000 employees in the forestry and logging sector, 556,000 in the wood products manufacturing sector and 468,000 in the paper sector. Forty percent of these employees (441,000) were employed in the Northern States (Table 16). Northern industries supported about 35 percent of the Nation's wood products jobs (194,000 out of 556,000 jobs) and 50 percent of pulp and paper manufacturing jobs (235,000 out of 468,000 jobs).

Quantifying Employment in the Forest Products Manufacturing Sector

The forest products manufacturing sector in the United States is comprised of primary wood products and pulp and paper manufacturers (NAICS 321 and 322). In 2006, the sector employed an estimated 7.3 percent of all manufacturing-related workers and 8.2 percent of all U.S. production workers. The more general category of "manufacturing-related jobs" consists of the average number of production workers plus the number of other employees engaged in factory supervision above the line-supervisor level, sales, sales delivery, advertising, credit, collection, installing and servicing of own products, clerical, executive, purchasing, financing, legal, personnel, professional, and technical activities. The category "production jobs" includes individuals—up through the line-supervisor level—engaged in fabrication, processing, assembly, inspection, receiving, storage, handling, packing, warehousing, shipping but not delivery, maintenance, repair, janitorial services, guard services, product development, auxiliary production of power and other inputs for a plant's own use, recordkeeping, and other services closely associated with these production operations. Neither category includes proprietors and partners of unincorporated businesses (U.S. Census Bureau 2009).

Table 16—Number of jobs in forestry and logging (NAICS113), wood products (NAICS 321), and pulp and paper industries (NAICS 322) of the North in 2006 (U.S. Bureau of Labor Statistics 2007a).

State and region	Forestry and logging	Wood products	Pulp and paper[a]	Total
Connecticut	19	1,745	4,886	6,650
Delaware	--[b]	419	951	1,370
Illinois	171	9,209	24,841	34,221
Indiana	455	19,399	11,488	31,342
Iowa	32	12,549	4,342	16,923
Maine	2,732	6,213	9,040	17,985
Maryland	416	3,568	5,249	9,233
Massachusetts	149	3,378	12,311	15,838
Michigan	1,662	10,737	13,966	26,365
Minnesota	841	16,320	11,866	29,027
Missouri	235	10,437	8,758	19,430
New Hampshire	470	2,758	2,228	5,456
New Jersey	23	4,559	14,070	18,652
New York	934	9,712	20,171	30,817
Ohio	613	16,476	24,726	41,815
Pennsylvania	832	30,291	26,843	57,966
Rhode Island	--	--	1,339	1,339
Vermont	--	2,283	1,291	3,574
West Virginia	1,174	8,252	723	10,149
Wisconsin	970	25,898	36,008	62,876
North total	11,728	194,203	235,097	441,028
U.S. total	72,140	556,110	468,422	1,096,672
North as a percent of U.S. total	16	35	50	40

[a]*The paper category includes manufacturers of converted paper products such as packaging and stationery.*

[b]*Not disclosed.*

Fig. 50 shows how national annual average employment fluctuated in forestry and logging, wood products manufacturing, and pulp and paper. From 2003 to 2006, the average number of employees in wood manufacturing increased slightly, but employment declined in 2007, partly as a result of a slowing economy. Declines were more severe in the pulp and paper industry, and the logging industry remained steady.

Wages, income, and injury rates in the forest sector

In 2006, total U.S. wages in the wood products and paper manufacturing industries represented 8 percent of wages paid to production workers across all manufacturing sectors (U.S. Census Bureau 2009). Workers in the North earned 41 percent of U.S. wages paid collectively in the forestry and logging (14 percent of U.S. total), wood products (35 percent), and pulp and paper manufacturing (49 percent) sectors (Table 17).

The wage rates of workers in northern wood products and pulp and paper manufacturing industries were similar to national averages for these industries, but northern wage rates for forestry and logging were only at 85 percent of the national average. Forestry and logging workers in Massachusetts were paid an average of $50,000 per year, the highest of any Northern State and twice as much as their counterparts in Illinois received in average annual wages. Average annual wages were more than $51,000 in the North paper industry, compared to a little over $34,000 for wood products and $29,000 for forestry and logging.

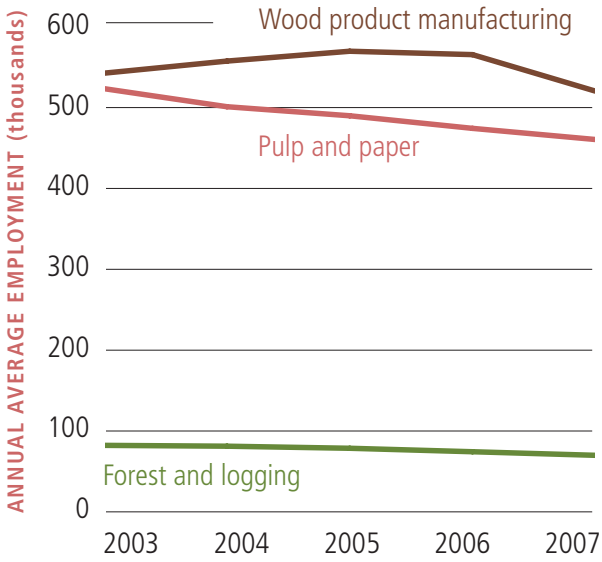


FIGURE 50

National annual average employment in forestry and logging, wood products manufacturing, and pulp and paper industries (U.S. Bureau of Labor Statistics 2007a).

Table 17—Total wages and average wage rates of workers in forestry and logging (NAICS 113), wood products (NAICS 321) and pulp and paper (NAICS 322) industries in the Northern States, 2006. (U.S. Bureau of Labor Statistics 2007a).

State and region	Forestry and logging	Wood products	Pulp and paper[a]	Forestry and logging	Wood products[a]	Pulp and paper
	(thousands of dollars)			(dollars per worker per year)		
Connecticut	572	76,705	309,562	30,131	43,957	63,357
Delaware	-- [b]	15,912	50,801	--	37,975	53,418
Illinois	4,275	324,258	1,242,423	25,000	35,211	50,015
Indiana	11,417	637,781	516,374	25,092	32,877	44,949
Iowa	839	464,564	199,854	26,208	37,020	46,028
Maine	92,552	205,483	543,638	33,877	33,073	60,137
Maryland	11,851	131,445	222,447	28,489	36,840	42,379
Massachusetts	7,468	140,467	635,211	50,121	41,583	51,597
Michigan	50,071	375,366	713,537	30,127	34,960	51,091
Minnesota	25,084	766,616	649,960	29,826	46,974	54,775
Missouri	5,690	280,620	394,241	24,214	26,887	45,015
New Hampshire	17,235	111,285	114,965	36,671	40,350	51,600
New Jersey	1,035	174,792	839,838	45,007	38,340	59,690
New York	28,954	342,066	995,661	31,000	35,221	49,361
Ohio	14,424	531,005	1,167,389	23,530	32,229	47,213
Pennsylvania	20,550	986,426	1,349,183	24,699	32,565	50,262
Rhode Island	--	--	53,259	--	--	39,775
Vermont	--	77,768	65,434	--	34,064	50,685
West Virginia	25,790	245,596	28,123	21,968	29,762	38,897
Wisconsin	26,611	816,305	1,949,581	27,434	31,520	54,143
North total	344,419	6,704,460	12,041,480	29,367	34,523	51,219
U.S. total	2,502,632	19,278,736	24,825,898	34,691	34,667	52,999
North as a percent of U.S. total	14	35	49	85	100	97

[a]*The paper category includes manufacturers of converted paper products such as packaging and stationery.*

[b]*Not disclosed.*

Data from 2003 to 2007 show declines in recordable injury rates in the U.S. forestry and logging, wood products, and pulp and paper manufacturing industries (Fig. 51). Nevertheless, the injury rate for wood product manufacturing was higher than the mean rate for other U.S. manufacturing industries. In contrast, injury rates in the forestry and logging and the pulp and paper manufacturing industries tend to be lower than the overall manufacturing averages in the United States.

From 2003 to 2008, 131 job-related fatalities occurred in the North forestry and logging, wood products, and pulp and paper manufacturing industries, or about 14 percent of the national total. Given that 40 percent of the total national workforce for these industries is employed in Northern States, this fatality rate is relatively low, suggesting that working conditions are safer in the North than in other parts of the country. Fatalities were most common in forestry and logging, accounting for 79 percent of total forest industry fatalities and exceeding the national average of 66 percent. The fatality rate for the northern forestry and logging sector was high considering that only 12,000 workers (out of 441,000 total workers in all northern forest industries) were in that sector. However, Tables 16 and 18 show that region's proportion of the nationwide forestry and logging fatalities (17 percent) is consistent with the region's proportion of nationwide forestry and logging jobs (16 percent). The Northern States employed 35 percent of the national wood products workforce with only 10 percent of that industry sector's fatalities reported nationally and 49 percent of the national pulp and paper workforce with only 6 percent of the fatalities reported nationally. These relatively low incidences may suggest safer working conditions for northern workers in these industries compared to the rest of the country (Table 18).

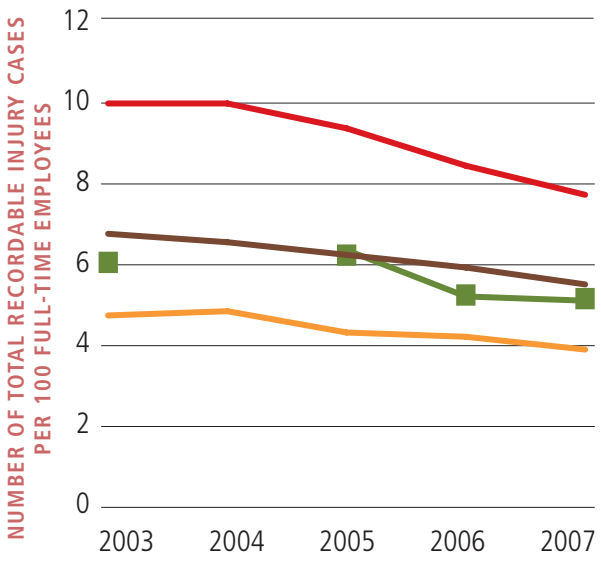


FIGURE 51

National total recordable injury cases in the forestry and logging industry, wood products manufacturing, pulp and paper industries; and total U.S. manufacturing (U.S. Bureau of Labor Statistics 2009).

Table 18—Total fatalities reported, 2003 to 2008, in the Northern States by forest products industry (U.S. Bureau of Labor Statistics 2007a).

Industry category	Northern States fatalities	National fatalities	Northern States proportion
	(number)	(number)	(percent)
Forestry and logging (NAICS 113)	103	617	17
Wood products (NAICS 321)	22	229	10
Pulp and paper (NAICS 322)	6	95	6
Total	131	941	14

Recreation and tourism

The forest land that covers 42 percent of the North offers vast opportunities for forest-based recreation. About 85 percent of the total 172 million acres of forest land in the region is available for recreation, but open access to the public varies by ownership group. Nearly all the 44 million acres of public forest land is open to the public for various forms of recreation. In contrast, only about 18 percent of the 100 million acres of nonindustrial private forest land is open for public recreation. Nevertheless, more than 90 percent of that private land is used for recreation by owners, their families, associates, or lessees. The remaining owner group, private corporations, own 28 million acres of forest land, of which roughly 40 percent is available for forest recreation (USDA FS 2011e, Cordell 2004).

Compared to other regions of the United States, the North has a small portion of Federal forest land (6 percent of the U.S. total), and little wilderness (1.5 percent of the U.S. total). However, Northern States have 7,300 miles in the National Recreation Trail System, more than other comparably sized regions of the U.S. Moreover, designated trail mileage in the Northern States increased by 77 percent from 2004 to 2009 (Cordell et al. in press).

In Northern States the most common nature-based recreation activities are walking, participating in family gatherings, gardening or landscaping, and viewing or photographing nature. The fastest growing nature-based recreation activities in the North from 1999 to 2009 were, visiting a farm or agricultural setting, gathering wild-grown edibles, off-road driving, viewing or photographing wildlife or natural environments, warm-water fishing, and day hiking (Table 19). For many forest recreation activities in the United States the majority of participation occurs on public lands and much takes place on urban forest land. Urban and community forests comprise relatively few acres compared to rural forests (see subsequent sections), but are heavily used because of their proximity to people.

Table 19—Participation in nature-based activities from 2005 to 2009 in the North for activities with greater than 10 million participants age 16 and older, and corresponding change in participation 1999 to 2009 (Cordell at al. in press)

Activity	Mean portion of population participating 2005-2009	Participation change 1999-2009
	(percent)	
Walk for pleasure	85	6
Family gathering	75	7
Gardening or landscaping	67	3
View/photograph natural scenery	64	12
Visit outdoor nature center/zoo	57	5
Picnicking	55	1
View/photograph other wildlife	51	21
View/photograph flowers, etc.	51	23
Sightseeing	51	5
Driving for pleasure	50	4
Visit a beach	45	15
Visit historic sites	44	0
Swimming in lakes, ponds, etc.	44	8
Swimming in an outdoor pool	43	11
Bicycling	37	4
View or photograph birds	38	18
Gather mushrooms, berries, etc.	36	26
Visited farm or agricultural setting	36	28
Day hiking	33	15
Visit a wilderness	31	11
View or photograph fish	25	13
Warmwater fishing	25	17
Motorboating	24	5
Visit waterside besides beach	24	2
Sledding	21	5
Developed camping	21	-10
Mountain biking	20	-6
Boat tours or excursions	19	-2
Visit prehistoric sites	19	3
Drive off-road	18	25
Canoeing	12	8
Primitive camping	12	-3

Walking for pleasure and viewing or photographing nature are among the most common forest recreation activities, in rural as well as urban forests

Ash Cave, Hocking Hills Region, Ohio

The population density is higher in the North than other regions, so the total number of nature-based recreation activity days is greater than elsewhere and concentrated on the relatively few forested acres per capita. However the recent rate of population increase in the Northern States has been slower than for other quadrants of the United States and shows considerable variation among age classes. Population increases in the North have been concentrated in age groups between 45 and 64 years with net population decreases for age cohorts greater than 64 years old, 25 to 34 years old, and less than 6 years old. Thus, recreation choices by members of the current 45-to-64-years-old age cohort will strongly influence nature-based recreation trends in the coming decade (Cordell et al. in press).

The North's large proportion of private forest land, combined with its large population, results in a strong recreation and tourism industry. About half the Nation's 1,600 privately operated campgrounds and recreational vehicle parks are in the North, as are the majority of privately operated downhill skiing facilities and forest-based nature parks. Forest-based sightseeing and transportation businesses are also concentrated in the eastern United States. (Cordell 2004). Seasonal homes are another significant part of the recreation and tourism industry. The States with the highest proportions of seasonal homes nationally were Maine (16 percent seasonal homes), Vermont (15 percent), and New Hampshire (10 percent); Wisconsin ranked eighth with 6 percent (U.S. Census Bureau 2000). These seasonal homes—common across the northern forests in New England, the Adirondacks, the upper Great Lakes, Missouri Ozarks, and other mainly nonmetropolitan places with forests, lakes, rivers, and mountains—function as family housing for vacations, providing ready access to outdoor recreation and informal workplaces for long weekends. Later in life, seasonal homes may become the retirement home (Stewart and Johnson 2006, Stynes et al. 1997).

The importance of forests to people

Many people value and appreciate the forest environment itself; the importance of forests extends beyond what can be extracted from them to what they are, whether they are used or not. The directly experienced features and qualities of the forest environment are one aspect of their importance to society. Aesthetic experiences in outdoor settings are often among the most important experiences in people's lives. Sometimes the experiences that people have in natural environments are strongly felt, but hard to put into words. Emotional experiences of this kind may carry a sense of awe, wonder, joy, and deep meaning; and may directly influence quality of life. Positive experiences in natural environments serve as significant sources of meaning and happiness, often leading people to form strong emotional attachments that can in turn influence second-home development and vacation choices. This can become a source of controversy in natural resource management if management actions threaten to change the character of places where people have formed strong attachments. It is critical for resource managers and planners to recognize the importance of sense of place, to understand why people consider certain places to be special, and to consider how such places may be affected by land management and development policies.

Criterion 7:

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

Montréal Process Criterion 7 (Montréal Process Working Group 2010); Northern Area Forest Sustainability Indicators 15.3–15.5, 17.1, 17.2, 18.1-18.6 (USDA FS 2010d)

The importance of legal, institutional, and economic frameworks for forest conservation and sustainable management

This criterion focuses on the social context of forests—the laws, policies, administrative rules, and social and economic institutions—that governs forest resource management and use. What society permits or restricts, encourages or discourages all influence the sustainability of forest resources. Criterion 7 captures this by turning attention to all the different social institutions that create and enforce rules about resource management and use.

Many of the criteria included in this assessment provide baseline measures, analyzing current conditions and providing a starting point for projecting future conditions (among others, how much land is forested and how many species are at risk). This criterion is different in that it addresses the likely characteristics of change. Forest sustainability is less likely where there are no rules or guidelines protecting resources or where laws and regulations are not enforced; more likely where society has developed social institutions to guide forest management.

Indicators of the legal, institutional, and economic frameworks for forest conservation and sustainable management in northern forests

From the broad range of institutions and practices that can be considered under Criterion 7, we focus on three: (1) forest-related planning and implementation, (2) best practice codes (or best management practices) for forest management, and (3) management of forests to conserve special values.

Forest planning and policy review; and opportunities for public participation in decisionmaking

Planning, assessment, and policy review provide regular opportunities to view forest management from a long-term perspective. Because these activities involve significant efforts to communicate with and involve the public, they also constitute opportunities for public participation in public policy and decisionmaking.

Under the Montréal Process, broad participation in resource management is encouraged, so that people interested in, but without an official role in decisionmaking (often referred to as "stakeholders") have opportunities to voice their opinions about forest policies and management activities. Stakeholders can include local residents, recreational forest users, business people whose livelihood is directly or indirectly tied to forests, technical experts (whether they

Key Findings for Criterion 7

- Each Northern State recently completed a forest resource assessment and strategy.
- 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 varies widely. Unlike water and soils and wildlife/biodiversity standards, silvicultural best practice codes are seldom mandatory.
- 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.

are affiliated with a management agency or not), or none of the above. What they all have in common is an interest in the fate of a particular forest or forest resource.

Unlike top-down, expert-based management, a participatory process emphasizes joint discovery, where managers learn from, as well as educate, their stakeholders. In many situations, this inclusive style of decisionmaking is more conducive to positive change and innovation than the closed model that was pervasive in the middle of the last century. Collaboration also recognizes the significance of forest management decisions for local communities. Because their economic prospects and quality of life are often directly affected by decisions made in the forest planning process, communities need to be involved in forest planning (Steelman 2001).

Public involvement is a part of virtually all major forest plans, forest plan revisions, and assessments for public lands; and some policy reviews. Public hearings or meetings bring together people who are not regularly involved in forest management, brief them about future issues and options, and hear their views about the strategic direction of forest management. Sustainability efforts can benefit from activities that broaden discussion and debate because sustainability often requires innovation and changes in management practices and priorities. Whether the innovative ideas come from the forestry professionals or the public participants, the process benefits from broad discussion.

Forest-related planning, assessment, and policy review processes take place at all levels of government. Many are required by law and are revisited on a cyclical basis. Others, including the Northern Forest Futures Assessment, are special efforts that are not on a schedule for recurring. Regional assessments often focus on the issues and resources common across ownerships and across States. Variations in resources (human, natural, and fiscal) have less influence at this regional scale, allowing for a more informed perspective on society's progress toward achieving sustainability.

The 2008 Farm Bill modified the Cooperative Forestry Assistance Act requiring that State agencies develop forest resource assessments and strategic plans to be eligible for Federal funding (http://www.northeastern forests.org/FRPC/). In 2010, all State forestry agencies nationwide completed statewide forest resource assessment and strategy documents. Individual State assessments and strategies tier off the national plan and can be accessed through the National Association of State Foresters Web site (http://www.stateforesters.org/issues_and_policy/forest_in_the_farm_bill). Each State assessment includes a description of conditions and trends across all trees and forests; key forest-related threats, benefits, and opportunities; and priority landscape areas. Each State resource strategy addresses the issues and priority landscape areas highlighted in the assessment and identifies the resources needed to address the strategies. State forestry agencies engaged stakeholders and partners in the development of their assessments and strategies.

Table 20—Forest-related planning and assessment laws by Northern State.

State	Forest-related Planning (P) or Assessment (A)	Law	Year enacted
Massachusetts	A	Massachusetts Environmental Policy Act (MEPA) MGL Ch. 30 Sec. 61-62H; Regulations 301 CMR 11.00	1973
Maryland	A	Maryland Forest Conservation Act. Annotated Code of MD Section 5-1601 -- 5-1613	1991
	P	Renewable Forest Resource Plans. Annotated Code of MD Section 5-214	1979
Maine	P	Biennial report on the state of the State's forests 1997 12 MRSA 8879	1997
	A	An Act to Implement the Recommendations of the Majority of the Joint Standing Committee on Agriculture Conservation and Forestry Regarding Enhancing Forest Resource Assessment Public Law 97 Chapter 720	1997
	P, A	Forest Resource Assessment Program 1997 12 MRSA 8876	1997
	P	Forest Sustainability 1997 12 MRSA 8876-A	1997
	A	Determination of supply and demand for timber resources 1997 12 MRSA 8877-A	1997
Michigan	P, A	Part 525 Statewide Forest Resources Plan of the Natural Resources and Environmental Protection Act 1994 Public Act 451	1994
Minnesota	P, A	MN Forest Resource Management Act	1982
	P, A	Sustainable Forest Resources Act	1995
New Hampshire	P, A	RSA 227-I: 8 (originally RSA 220 effective 1981)	1995
New Jersey	P	NJ Stat. Ann 13:1L - 5 (WEST 1983)	1983
New York	P, A	Environmental Conservation Law Section 9 Title 8 Forest Resources Planning (9-0805)	1983
Rhode island	P	Chapter 42-11 of the General Laws of Rhode Island	
Wisconsin	P, A	Wisconsin Statute 28.04 State Forests	1949

State laws that facilitate or require forest-related planning or assessment are shown in Table 20. Planning involves the development of a future-oriented strategic document that outlines what kinds of management activities will be carried out in coming years. Assessment involves research that generates a comprehensive description of the current

status of resources, programs, events, and concerns. Ideally, any statewide plan would outline objectives based on information from a statewide assessment and would link to a set of broad goals developed in a previous plan, with new specific objectives arising from current concerns and events. Not surprisingly, planning and assessment activities are required by law in all States that have extensive forest resources.

As Table 21 shows, however, State forestry agencies are not the only organizations engaged in planning, nor are timber resources the only focus of planning; wildlife, recreation, and land use may also be considered part of natural resource planning. Table 21 illustrates the different purposes and targets of planning and assessment activity in the Northern States.

Unlike governments that manage their forests with specialized staffs and resources, private citizens with small parcels may be ill-equipped to develop their own plans for resource management. Forest landowners are offered planning and management assistance through State forestry programs, with funding, technical assistance, and support from U.S. Forest Service State and Private Forestry (Figs. 52 and 53). Forest stewardship plans are of particular value for forest sustainability. Consulting foresters or State forestry staffs work with landowners to determine management goals, assess resources, and develop plans for operations and activities, including harvesting, timber stand improvement work, and wildlife habitat protection and maintenance.

Table 21—Forest planning (2000 to 2005) and advisory (2006) activity for Northern States (National Association of State Foresters 2009).

Type	State																			
	CT	DE	IA	IL	IN	MA	MD	ME	MI	MN	MO	NH	NJ	NY	OH	PA	RI	VT	WI	WV
Strategic agency/department plan		x	x		x	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Comprehensive statewide forest plan			x	x			x	x	x	x					x	x	x		x	x
State-owned forest land plan		x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Municipal-owned forest land plan			x			x		x		x							x	x		
County-owned forest land plan			x				x												x	
Statewide land-use plan					x		x	x		x		x	x				x	x	x	
Comprehensive wildlife plan		x	x	x	x		x	x	x	x	x							x	x	
Statewide recreation plan		x	x		x		x	x	x	x		x		x		x	x	x	x	
Watershed-based plan		x	x	x	x	x	x	x			x		x	x	x		x	x	x	x
Multi-state plan		x	x	x			x	x	x	x			x					x	x	x
Active forest advisory board in 2006	x	x			x	x			x	x	x	x	x		x	x		x	x	x

Ideally, the consulting forester is both a sounding board to help owners clarify their goals and intentions, and a source of expert information and experience about the potential for ensuring sustainability and other likely outcomes.

Variations in the number of plans among States are largely the result of differences in amount of forest acreage and the number of owners, but States also differ in the degree of emphasis they place on stewardship planning in relation to other activities. Because technical assistance from professional foresters is central to plan development, the number of plans and acres covered under stewardship plans is sensitive to changes in the Federal and State funding that support their availability. Approximately 10 percent of the northern nonindustrial private forest land acreage is managed under stewardship plans, but the covered area for individual States ranges from less than 5 percent to more than 30 percent (Table 22).

By 2006, all the National Forests in the 20 Northern States had completed forest plan revisions. National Forest plan revisions are intended to address broad issues that recur often across different forest projects and provide guidance for all major forestwide changes over a 10- to 15-year horizon. For example, because conducting silvicultural treatments and remodeling recreation facilities both can affect the visual character of a National Forest, visual character is an issue that might be addressed in the forest plan. Ongoing litigation since enactment of the National Forest Management Act in 1976 has slowed forest planning and forest plan revision on National Forests, and current efforts focus on issues that are widely acknowledged to need attention.

Across all levels of government, "sunshine" laws that require transparency and access to official government activities have been enacted to support public participation. Laws requiring open meetings, which date back to the 1970s and are present in various forms in all States, ensure that the public and the press have the right to know about upcoming meetings in which government employees will address land management, planning, and other activities that may be of interest to stakeholders. Through these laws, public access to documents and public involvement in decisionmaking have become a more formal and intentional part of government operations in the United States.

Formal advisory boards can also be established to seek outside input (shown in Table 21). Fourteen of the 20 Northern States have active forest advisory boards that regularly meet with the State forester and her/his staff. They are typically made up of key stakeholders, natural resource specialists, government natural resource agencies, nonprofit organizations, and resource interest groups.

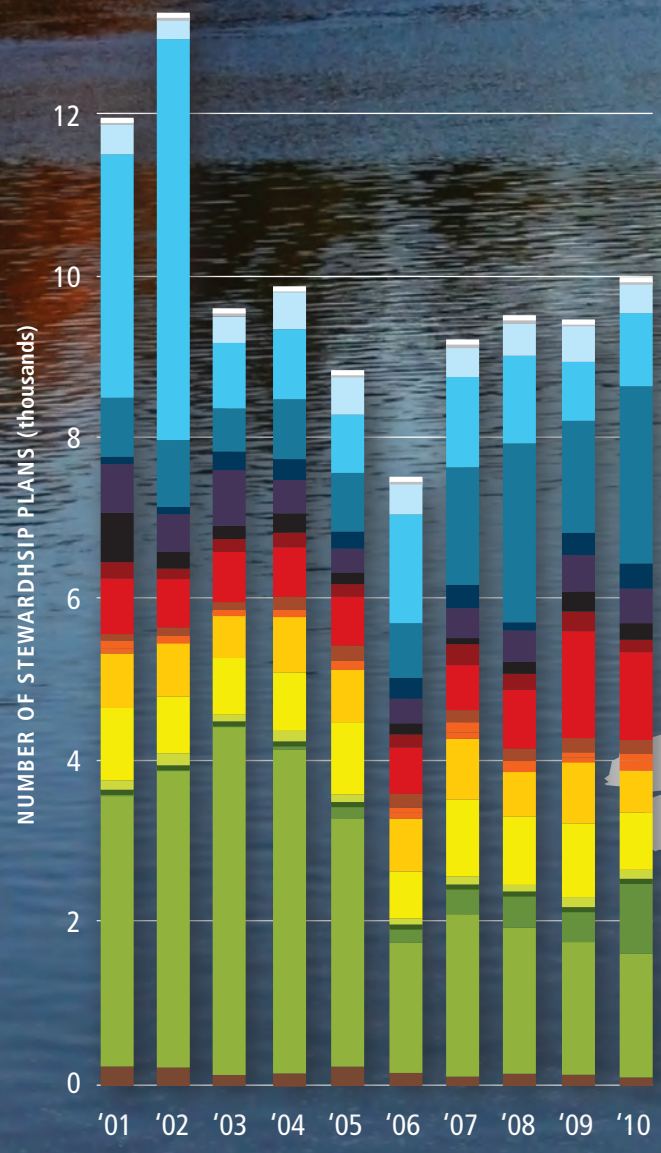


FIGURE 52

Number of new or revised stewardship plans by Northern State, 2001 to 2010.

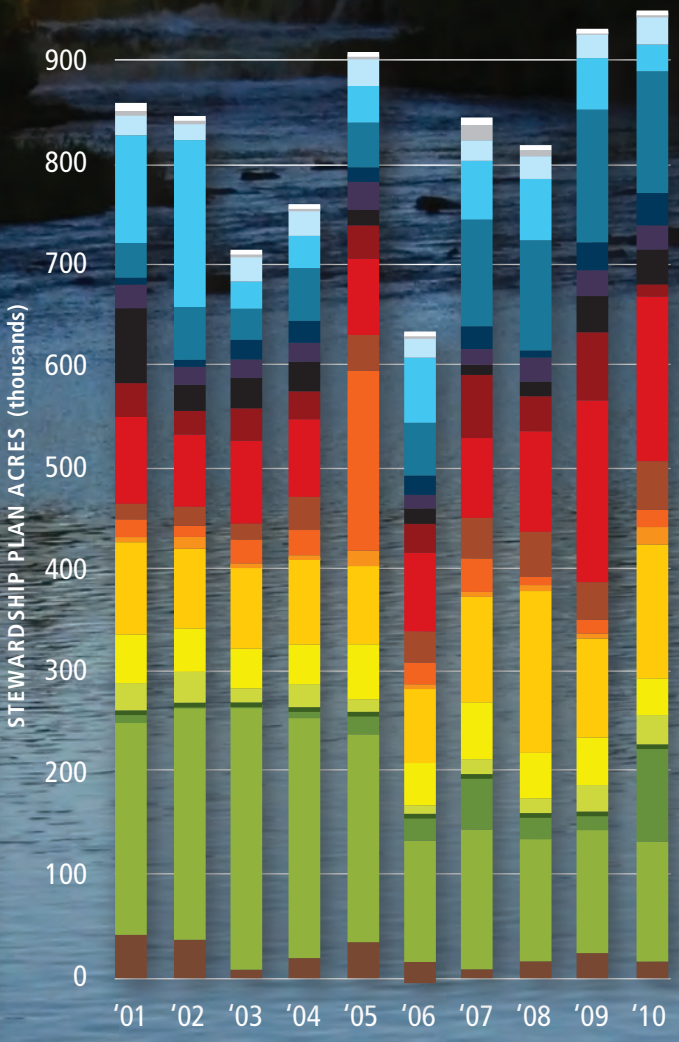


FIGURE 53

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

Table 22—Cumulative area of private, noncorporate forest land covered by active forest stewardship plans, 2010. States are ordered from highest to lowest proportion of stewardship plan coverage.

State	Private noncorporate forest area[a]	Cumulative area under forest stewardship plans[b]	Proportion of area under stewardship plans
	(1,000 acres)		(percent)
Wisconsin	9,674	2,985	31
New Hampshire	2,844	634	22
Maryland	1,462	324	22
Illinois	3,509	628	18
Delaware	244	39	16
Minnesota	5,921	860	15
New Jersey	805	115	14
Massachusetts	1,998	276	14
Indiana	3,588	463	13
Iowa	2,511	295	12
Ohio	6,064	520	9
New York	12,190	975	8
Pennsylvania	9,6030	531	6
West Virginia	7,174	270	4
Vermont	3,109	110	4
Connecticut	1,148	39	3
Maine	6,261	210	3
Missouri	11,755	343	3
Rhode Island	251	7	3
Michigan	9,458	203	2
North total	99,569	9,828	10

[a]*From Smith et al. (2009).*
[b]*From State data in the Performance Measurement Accountability System, via Michael Huneke, U.S. Forest Service. (8 February 2011).*

Best practice codes for forest management

Best practice codes (or best management practices) are recommendations for working on the land. They capture and maintain the collective wisdom society has about how to protect the environment during operations such as harvesting and road building. Unlike the strategic plans and assessments discussed above that operate at a large scale and a long time horizon, these standards and guidelines are meant to regulate daily, routine activities undertaken in the course of (often) small projects.

Almost all Northern States have some standards and guidelines across three general areas of management; silviculture, water and soils, and wildlife or biodiversity (Table 23). Best practice codes can be voluntary or mandatory recommendations, guidelines, or standards. Once established, their effectiveness depends on whether they are maintained and whether their use is promoted. The need to monitor the implementation and effectiveness of standards and guidelines is generally recognized, but not always supported. Without monitoring, the potential exists for discrepancies between intentions and actual behavior. The voluntary nature of many guidelines means that implementation is not certain, and effectiveness is largely unknown, although some States have adopted a regional-level protocol for monitoring effectiveness.

Mandatory standards and guidelines are commonly the result of legal requirements, often those associated with environmental regulations such as the National Environmental Policy Act and the Clean Water Act. Monitoring the implementation and effectiveness of standards and guidelines may also be carried out in response to Federal requirements. Federal environmental legislation also accounts for the differences among the three sets of standards and guidelines: silvicultural guidelines (seldom mandatory), water and soils (often mandatory), and wildlife/biodiversity standards (often mandatory). Federal regulation to implement legislation and the mandatory nature of many State standards and guidelines for water quality and biodiversity also reflect the sensitivity of these systems to poor management.

On private land, few standards and guidelines are mandatory and monitoring is uncommon, primarily because of hesitancy to be perceived as violating private property rights and the practical difficulties of accessing private lands.

Management of forests to conserve special values

The terms of sustainability as set forth in the Montréal Process require that society consider both basic needs, such as fiber and energy production, and conservation. Conserving special forest values—environmental, cultural, social, or scientific—through management is one of the primary motivations for many in the forestry profession, and its significance is reflected here. Forests are not sustainable by the Montréal Process definition unless these special values are preserved.

Table 23—Management standards and guidelines and their monitoring across ownership types, by Northern State, whether mandatory (M) or voluntary (V) and whether measuring compliance (C) or effectiveness (E).

	Silviculture				Water, soils				Wildlife, biodiversity			
	State forest		Private forest		State forest		Private forest		State forest		Private forest	
State	Standard or guide	Monitoring	Standard or guide	Monitoring	Standard or guide	Monitoring	Standard or guide	Monitoring	Standard or guide	Monitoring	Standard or guide	Monitoring
CT												
DE	M	C			M	C	M	C				
IA	M	C, E	V		M	C,E	V		M	C,E	V	
IL		E	V			E	V					
IN	M		V		M	C,E	V		M		V	
MA	M	C,E			M	C,E			M	C,E		
MD	V	C,E			M	C,E	M					
ME	V	C,E			V	C,E	V	C,E	V	C,E		
MI		C			M	C	V		M	C		
MN	V	C	V	C	V	C	V	C	V	C	V	C
MO		C,E	V		M	C,E	V		M	C,E	V	
NH	V		V		M	C	M	C				
NJ		C,E	V	C	M	C	M	C		C	V	C
NY		C	V			C	V			C	V	
OH	M	C	M		M	C	M		M	C	M	
PA	M	C	V		M	C	M	C	M	C,E	V	
RI	M	C,E	V	C	M	C,E	V	C	M	C	V	
VT	V		V		M	C	M	C,E	V		V	
WI	V	C	V,M	C	V,M	C,E	V,M	C,E	V,M	C	V,M	C
WV			V		M	C	M	C			V	

In the North, where private and other non-Federal ownerships account for 92 percent of forested land, conservation of habitats must be coordinated among owners, each perhaps controlling only a small portion of a critical landscape. For this reason, clear, enforced property rights are also important, because agreements that transfer, trade, or sell some of these rights (for example, development rights) are key to the success of conservation schemes in mixed landscapes.

The United States has a long history of forest conservation that continues today. Yellowstone, one of the World's first national parks, was established in 1872. Also established in the late 1800s, the forest reserves (now the national forests) protect water and provide timber. The passage of the Wilderness Act in 1964 provides additional protections for millions of acres of forest throughout the Nation.

Protected areas set aside land and water resources (including forests) in perpetuity to preserve natural ecosystems and provide refuges for species of concern. The maps in Figure 54, which distinguish protected forest

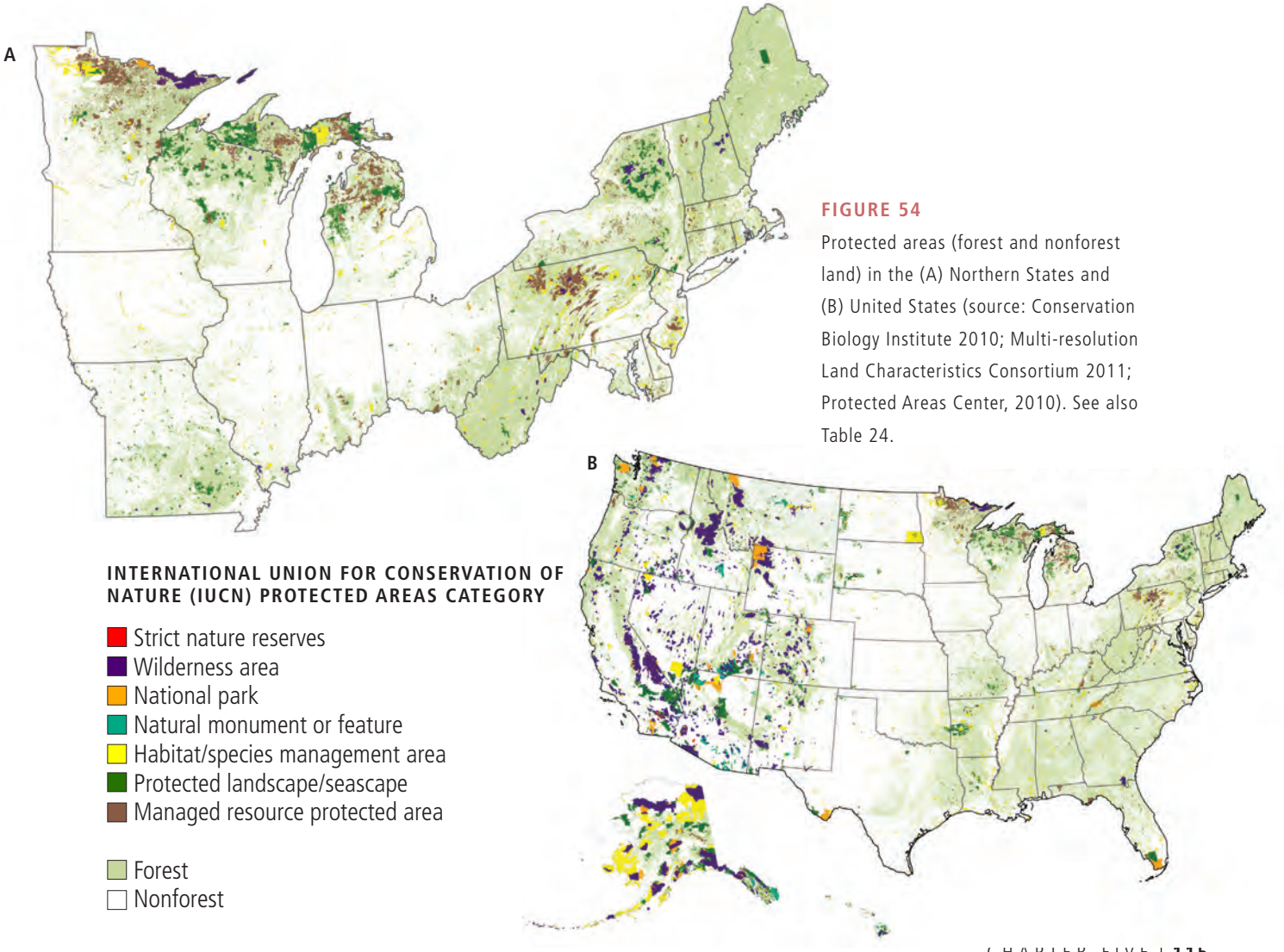


FIGURE 54

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). See also Table 24.

land from other protected land, are based on the latest version of the Conservation Biology Institute Protected Areas Database, a comprehensive geospatial data set (including detailed information on land ownership, management, and conservation status) of all protected areas in the United States. (Conservation Biology Institute 2010, Protected Areas Center 2010).

In addition to major Federal and State-owned protected areas such as national parks, State parks, and wildlife refuges, this database also focuses on lands managed by local governments (such as county forests) and nongovernmental organizations (such as The Nature Conservancy's reserves). Protected areas are classified into six categories ranging from (I) strict nature reserves and wilderness areas to (VI) managed resource protected areas (International Union for Conservation of Nature 1994, 2010; DellaSalla 2001).

Total U.S. protected area acreage, both forested and nonforested, is concentrated in the West and Alaska, predominantly on Federal lands. To determine whether the spatial distribution of protected forest land is more balanced, we estimated the area of forest land by protected category at a 0.22 acre (0.09 ha) spatial scale by intersecting a digital map of forest/nonforest cover with the protected area map boundaries. That analysis showed that 16 percent of northern forest land (27 of 172 million forested acres) falls in a protected category (Table 24), nearly identical to the entire United States, and larger than the conterminous States (13 percent). Compared to the United States as a whole, the North has relatively little forest area in the three most restrictive protected categories and relatively abundant forest area in the least restrictive category.

The protected forest area is concentrated in the Lake States, where the Boundary Waters Canoe Wilderness Area in northern Minnesota encompasses 1.1 million acres of the Superior National Forest; and New York, where the nearly 3-million acre Adirondack and Catskills Reserves were set aside nearly 100 years ago to be managed by the State as "wild forever."

If protected areas are not large enough or widespread enough to support the full range of habitat attributes needed to sustain all ecosystem components, areas outside protected status may be enlisted to contribute to biodiversity goals. The ability to manage both public and private unprotected forest lands for these broader goals depends on the objectives of the owners and their willingness to consider management options that can be integrated with those established for protected areas. One working example is the North Maine Woods, within whose boundaries are over 3.5 million acres of commercial forest land (North Maine Woods 2010), two wild northeastern rivers (the St. John and the Allagash), and the Allagash Wilderness Waterway. This organization of landowners—corporations, individuals, and families—have joined with Maine's natural resource agencies in a partnership to address landscape-scale management issues.

Table 24—Protected forest area and percent by International Union for Conservation of Nature (IUCN) protected status category.

Protected status	Total U.S. protected forest land		Conterminous U.S. protected forest land		Northern States protected forest land	
	Area	Proportion	Area	Proportion	Area	Proportion
	(1,000 acres)	(percent)	(1,000 acres)	(percent)	(1,000 acres)	(percent)
Strict nature reserve[a]	560	0.1	521	0.1	7	<0.01
Wilderness area[a]	30,439	4.1	24,847	4.0	1,796	1.0
National park[b]	8,056	1.1	6,548	1.1	820	0.5
Natural monument or feature[c]	4,195	0.6	1,595	0.3	25	<0.01
Habitat /species management area[d]	33,771	4.5	12,857	2.1	4,355	2.5
Protected landscape[e]	30,046	4.0	19,676	3.2	8,951	5.2
Managed resource protected area[f]	14,416	1.9	12,667	2.0	11,415	6.6
Total protected forest land	121,485	16.2	78,711	12.6	27,370	15.9
Total area of all forest land	751,228	--	622,611	--	172,039	--

[a]*Category I: an area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring or a large area of unmodified or slightly modified land, and/or sea, retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition. Strict nature reserves (Ia) are distinguished from wilderness areas (Ib).*

[b]*Category II: a natural area of land and/or sea, designated to (1) protect the ecological integrity of one or more ecosystems for present and future generations, (2) exclude exploitation or occupation inimical to the purposes of designation of the area, and (3) provide a foundation for spiritual, educational, recreational, and visitor opportunities, all of which must be environmentally and culturally comparable.*

[c]*Category III: an area of land and/or sea containing one or more specific natural or natural/cultural features which are of outstanding or unique value because of their inherent rarity, representative or esthetic qualities, or cultural significance*

[d]*Category IV: an area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.*

[e]*Category V: an area of land with coast and sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant esthetic, ecological, and/or cultural value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the protection, maintenance, and evolution of such an area.*

[f]*Category VI: an area of land and/or sea containing predominantly unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs protected forest.*

Another example of integrating protected areas with areas managed for multiple and sustainable uses is the Wisconsin County Forests Association—more than 2.3 million acres of county forests established by the Wisconsin legislature for open access to a range of users, from hunters to hikers to birdwatchers. This is the only association of its kind in the United States.

The conservation of special forest values in northern forests depends on programs that enable foresters and other natural resource professionals to work with individual forest landowners as well as governments and nongovernmental organizations. Continuing parcelization and turnover in ownership is a source of concern because these changes can jeopardize previous resource-management arrangements and agreements. Conserving the land and its wide array of values is not simple. For example, setting aside protected areas does not prevent housing growth from fragmenting surrounding landscapes, and protected areas are typically too small to exist as islands cut off from other biological resources (Radeloff et al. 2010). However, forest land preservation agreements and forest stewardship plans that keep land in private ownership and preserve traditional land-use values (such as those that support working family farms and ranches) can offer viable options for maintaining natural forest areas and preserving water quality in the face of land development pressure. This requires planning and management groups to work across larger landscapes, regardless of ownership patterns, in an effort to understand, manage, and protect their resources in common.

Sustainability relies heavily on the many organizations that teach, communicate, and support resource management. These include professional associations for resource managers (such as regional, State, and local chapters of the Society of American Foresters), student associations (such as Future Farmers of America, 4-H, and the Student Conservation Association), educational institutions at all levels, nongovernmental organizations, and ad-hoc groups that organize around specific issues or events. All contribute significantly to sustainability, and most are locally controlled.

The university-based Cooperative Extension Service is another significant resource for achieving sustainability. Through education, research, and communication, it reaches a wide range of people—professionals and amateurs alike—who support the goals of the Montréal Process.

Criterion 8:

URBAN AND COMMUNITY FORESTS

The importance of urban and community forests

Urban and community forests are the trees and forests found in cities, towns, villages, and communities. This category of forest includes both forested stands and trees along streets, in residential lots, and parks. These trees within cities and communities provide many ecosystem services and values to both urban and rural populations. These benefits include:

- Carbon sequestration and storage
- Removal of air pollution, improving air quality; absorption of ultraviolet radiation; and reduced noise pollution
- Reduced air temperature, improving human comfort and reducing building energy use
- Reduced stormwater runoff, improving water quality
- Improved aesthetics contributing to human physiological and psychological well-being
- Community cohesion and increased property values

Key Findings for Criterion 8

- 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 percent is Vermont at 2.9 percent.
- 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.
- 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 46.8 percent, with the highest percent tree cover in New Hampshire (88.9 percent) and the lowest in Iowa (10.4 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 numerous and valuable ecosystem services.

Urban forest in Central Park in New York City.

Urban and community areas are defined by two U.S. Census Bureau definitions that overlap. Urban land is all the territory, population, and housing units located within urbanized areas or urban clusters, each with a core population density of 1,000 people per square mile and with surrounding areas that have lower population densities (U.S. Census Bureau 2007). Community lands are places that have geopolitical boundaries (such as cities, towns, or unincorporated named places) that may include all, some, or no urban land within their boundaries. As seen in Figure 55, urban land can be found outside community boundaries, and not all areas within communities are urban.

Urban land encompasses the more heavily populated areas (population density-based definition), and community land encompasses both urban and rural (non-urban) communities that are recognized by their geopolitical boundaries (political definition); and both definitions provide information about human settlements and the forest resources within those settlements. As some urban land exists beyond community boundaries and not all community land is urban (communities are often a mix of urban and rural land), the category of "urban or community" was created to understand forest attributes accumulated by the union of these two terms. People in the Northern States depend heavily on both urban and rural forests to sustain quality of life. The majority of people in the Northern States live in urban areas, so healthy urban trees and forests are particularly important for the quality of their environment, their health, and their well-being.

This section describes the extent of urban and community forests and their spatial distribution, and it provides estimates of some of their ecosystem services and values. Though the Montréal Criteria and Indicators could be applied to forests and trees in northern urban areas, much of the data that would be needed are not available, especially data on conservation of soil and water resources (Criterion 4), enhancement of long-term multiple socioeconomic benefits (Criterion 6), and legal, institutional and policy frameworks for sustainable management (Criterion 7).

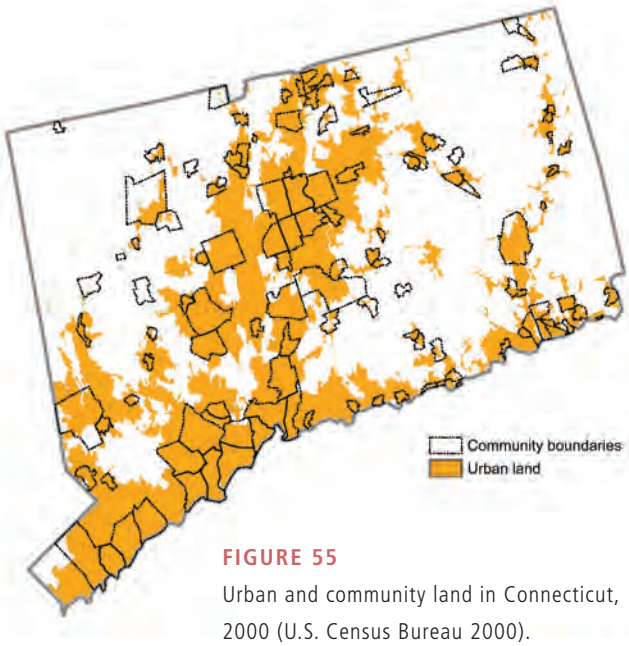


FIGURE 55
Urban and community land in Connecticut, 2000 (U.S. Census Bureau 2000).

However, data on biological diversity (Criterion 1), productive capacity (Criterion 2), ecosystem health (Criterion 3), and contributions to the global carbon cycle (Criterion 5) are partially available for cities that have completed urban forest assessments: New York, Syracuse, Baltimore, Minneapolis, Chicago, Boston, Jersey City, Philadelphia (Nowak et al. 2006a, 2006b, 2007a, 2007b). The focus of these assessments has been on monitoring, quantifying, and comparing the cumulative effects of urban forest ecosystem structure (such as species composition, size distribution, tree health, and leaf area) on ecosystem services and values (such as carbon storage and sequestration, energy use in buildings, air pollution removal, air temperature, stream flows, and water quality). Understanding and quantifying these relationships can lead to improved management plans in urban areas to sustain ecosystem and human health for future generations, but not without detailed data that are currently unavailable and have yet to be added to the U.S. Forest Service inventory and analysis protocols (Cumming et al. 2007, 2008; Nowak et al. 2007c).

Indicators for northern urban and community forests

Urban and community land in the North

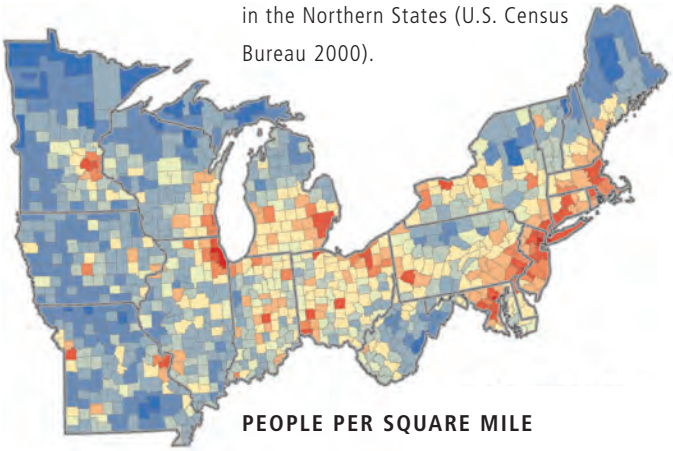
In 2000, 95 million people (80 percent) in the North lived in urban areas, and 86 million (71 percent) lived in communities (Table 25, Fig. 56). Six percent of the land was in urban areas, 6.3 percent was in communities, and 8.5 percent was in the combined urban or community category. Proportion of urban land varied from 1.1 percent in Maine to 38 percent in New Jersey (Table 26; Figs. 57 and 58). The U.S. areas with the highest percent urban land were the Northeastern States (10 percent) and the Southern Atlantic States (8 percent for Florida, Georgia, North Carolina, South Carolina, and Virginia combined). Areas with most urban land were the Northeastern (13 million acres) and North Central States (12 million acres), which together comprise the North (Nowak et al. 2005).

Urban growth in the North, 1990 to 2000

Urban land in the conterminous United States increased from 2.5 percent in 1990 to 3.1 percent in 2000, an increase in area about

FIGURE 56

Population density by county, 2000, in the Northern States (U.S. Census Bureau 2000).

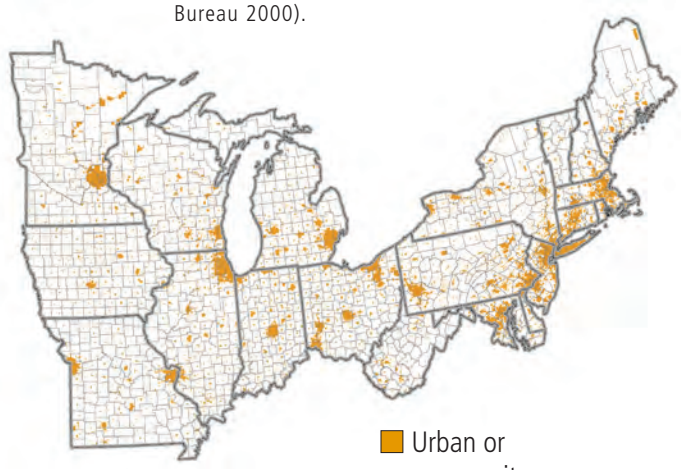


PEOPLE PER SQUARE MILE

- 3.1 to 10.0
- 10.1 to 25.0
- 25.1 to 50.0
- 50.1 to 75.0
- 75.1 to 100.0
- 100.1 to 250.0
- 250.1 to 500.0
- 500.1 to 1,000.0
- 1,000.1 to 5,000.0
- 5,000.1 to 66,940.1

FIGURE 57

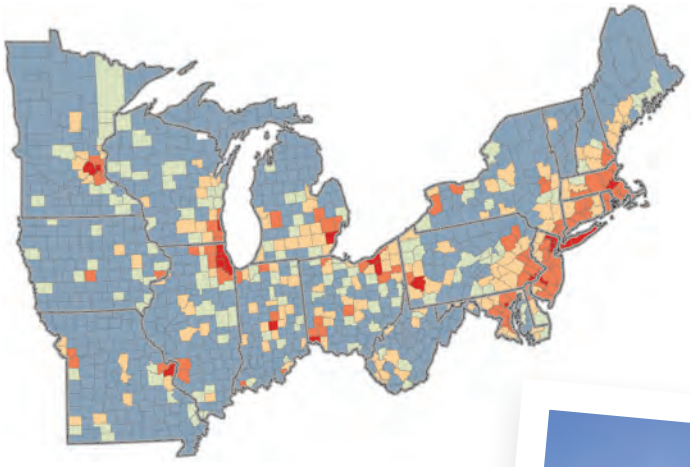
Urban or community land, 2000, in the Northern States (U.S. Census Bureau 2000).



- Urban or community land

FIGURE 58

Percent of county area classified as urban or community land, 2000, in the Northern States (U.S. Census Bureau 2000).



PERCENT

- 0
- 0.1 to 5
- 5.1 to 10
- 10.1 to 25
- 25.1 to 75
- 75.1 to 100

the size of Vermont and New Hampshire combined. States with the largest percentage increases (Table 27) were Rhode Island (5.7 percent), New Jersey (5.1 percent), and Connecticut and Massachusetts (5.0 percent each). Seven Northeastern States are among the 10 States with the greatest increase in percent urban land. States with the greatest absolute increase in urban land, were Florida (925,000 acres), Texas (871,000 acres), and California (737,000 acres).

Hartford, Connecticut

Table 25—Population characteristics in the Northern States and urban and community areas ordered from highest to lowest percent urban population.

State	Total for the State			Urban areas[a]				Communities[b]			
	Population, 2000 (1,000)	Percent change from 1990	Density (people per square mile)	Population, 2000 (1,000)	Population percent of State total	Percent change from 1990	Density (people per square mile)	Population, 2000 (1,000)	Population percent of State total	Percent change from 1990	Density (people per square mile)
New Jersey	8,414	8.9	1,136	7,939	94.4	14.9	2,847	6,059	72.0	10.5	3,064
Massachusetts	6,349	5.5	810	5,801	91.4	14.4	2,078	4,512	71.1	6.5	2,561
Rhode Island	1,048	4.5	1,004	953	90.9	10.4	2,477	746	71.1	2.5	3,446
Illinois	12,419	8.6	224	10,910	87.8	12.8	3,072	10,749	86.6	10.5	2,761
Connecticut	3,406	3.6	703	2,988	87.7	14.9	1,697	2,029	59.6	4.6	2,180
New York	18,976	5.5	403	16,603	87.5	9.5	4,241	15,351	80.9	6.1	4,164
Maryland	5,296	10.8	542	4,559	86.1	17.2	2,523	4,246	80.2	12.4	2,319
Delaware	784	17.6	401	628	80.1	29.0	2,084	345	44.0	34.6	2,004
Ohio	11,353	4.7	278	8,782	77.4	9.2	2,214	8,012	70.6	4.1	2,032
Pennsylvania	12,281	3.4	275	9,464	77.1	15.6	2,233	7,167	58.4	0.3	2,247
Michigan	9,938	6.9	175	7,419	74.7	13.2	2,233	6,384	64.2	5.1	2,219.7
Minnesota	4,919	12.4	62	3,490	70.9	14.2	2,331	3,939	80.1	16.3	996
Indiana	6,080	9.7	170	4,304	70.8	19.6	1,967	3,999	65.8	38.4	1,810
Missouri	5,595	9.3	81	3,883	69.4	10.5	2,142	3,862	69.0	8.7	1,344
Wisconsin	5,364	9.6	99	3,664	68.3	14.1	2,261	3,790	70.7	9.3	1,434
Iowa	2,926	5.4	53	1,787	61.1	6.2	2,204	2,272	77.6	6.7	1,178
New Hampshire	1,236	11.4	138	732	59.3	29.5	1,309	586	47.5	7.1	918
West Virginia	1,808	0.8	75	833	46.1	28.5	1,498	760	42.0	-1.2	1,010
Maine	1,275	3.8	41	513	40.2	-6.4	1,459	598	46.9	-2.3	498
Vermont	609	8.2	66	232	38.2	28.3	1,598	213	35.0	2.3	1,032
North total	120,079	6.9	186	95,485	79.5	13.1	2,489	85,617	71.3	8.2	2,094
Conterminous U.S. total	279,585	13.2	95	220,841	79.0	18.9	2,411	204,782	73.2	16.6	1,539

[a] *All the territory, population, and housing units located within urbanized areas or urban clusters, each with a core population density of 1,000 people per square mile and with surrounding areas that have lower population densities (U.S. Census Bureau 2007).*

[b] *Places that have geopolitical boundaries (such as cities, towns, or unincorporated named places) that may include all, some, or no urban land within their boundaries.*

Table 26—Urban and community land in Northern States ordered from highest to lowest percent urban or community land.

State and region	State land area	Proportion in urban[a] land	Proportion in community[b] land	Proportion in urban or community land
	(1,000 acres)	(percent)		
New Jersey	4,743	37.6	26.7	44.2
Massachusetts	5,018	35.6	22.5	40.4
Connecticut	3,099	36.4	19.2	39.9
Rhode Island	668	36.8	20.7	39.4
Maryland	6,252	18.5	18.7	23.4
Delaware	1,250	15.4	8.8	17.8
Ohio	26,123	9.7	9.7	12.6
Pennsylvania	28,633	9.5	7.1	12.4
New York	30,120	8.3	7.8	10.8
New Hampshire	5,749	6.2	7.1	10.3
Illinois	35,465	6.4	7.0	8.7
Indiana	22,895	6.1	6.2	8.1
Michigan	36,301	5.9	5.1	7.3
Wisconsin	34,652	3.0	4.9	5.6
Minnesota	50,866	1.9	5.0	5.2
Missouri	43,983	2.6	4.2	4.7
Maine	19,809	1.1	3.9	4.2
West Virginia	15,371	2.3	3.1	4.1
Iowa	35,681	1.5	3.5	3.6
Vermont	5,915	1.6	2.2	2.9
North total	412,594	6.0	6.3	8.5
Conterminous U.S. total	1,891,769	3.1	4.5	5.4

[a]*All the territory, population, and housing units located within urbanized areas or urban clusters, each with a core population density of 1,000 people per square mile and with surrounding areas that have lower population densities (U.S. Census Bureau 2007).*

[b]*Places that have geopolitical boundaries (such as cities, towns, or unincorporated named places) that may include all, some, or no urban land within their boundaries.*

Boston, Massachusetts

Autumn 'White Oaks' (Quercus alba) & prairie grasses, Waubonsie State Park, Iowa

Table 27—U.S. urban growth, 1990 to 2000 (Nowak et al. 2005).

State and region	Urban growth (acres)	Urban growth (percent of state)	Ranking for urban growth percent
Connecticut	159,000	5.0	3
Delaware	53,100	4.1	5
Maine	25,600	0.1	42
Maryland	199,400	3.0	6
Massachusetts	260,600	5.0	4
New Hampshire	103,100	1.7	11
New Jersey	253,100	5.1	2
New York	273,800	0.9	19
Pennsylvania	554,700	1.9	9
Rhode Island	40,500	5.7	1
Vermont	13,900	0.2	34
West Virginia	69,800	0.5	27
Northeast total	2,006,500	1.5	
Illinois	365,500	1.0	18
Indiana	287,200	1.2	15
Iowa	55,300	0.2	41
Michigan	381,900	1.0	17
Minnesota	150,800	0.3	32
Missouri	162,800	0.4	29
Ohio	363,500	1.4	13
Wisconsin	186,300	0.5	25
North Central total	1,953,400	0.7	
North total	3,959,900	1.0	
Florida	924,500	2.5	7
Georgia	694,800	1.8	10
North Carolina	653,600	2.0	8
South Carolina	286,700	1.4	12
Virginia	269,600	1.0	16
Southern Atlantic total	2,829,200	1.8	
Alabama	230,900	0.7	21
Arkansas	113,600	0.3	31

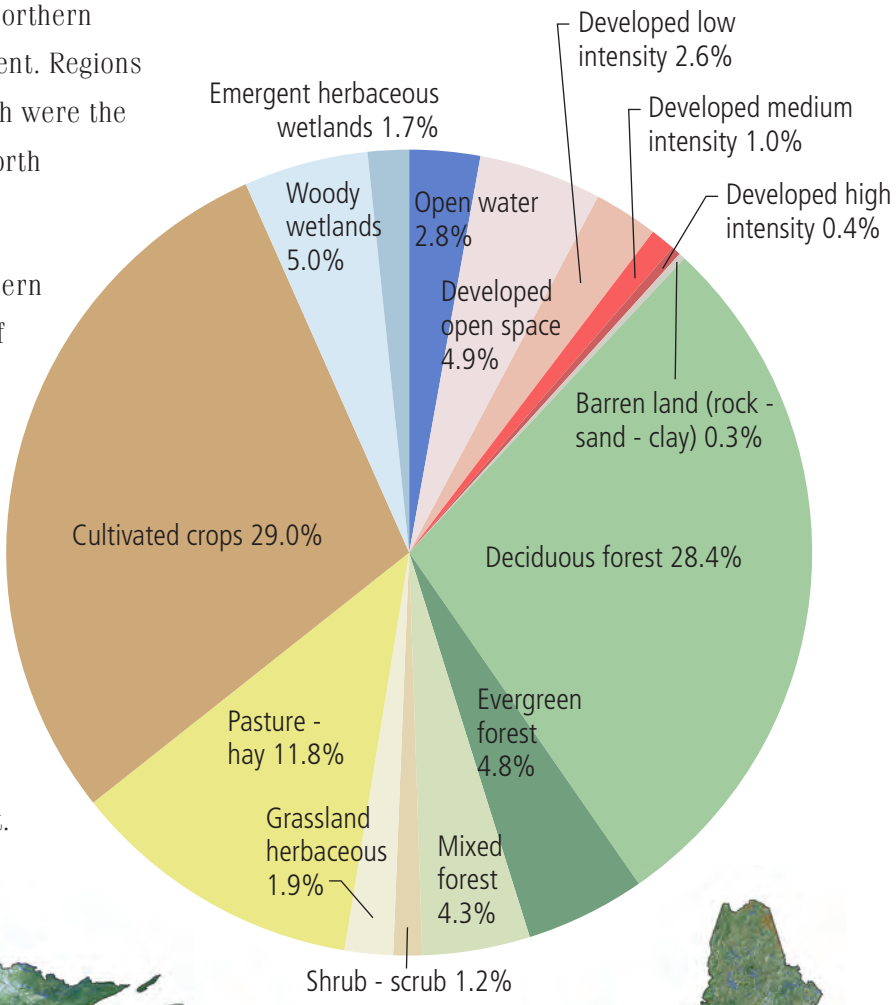
Table 27 continued

State and region	Urban area (acres)	Urban area change (percent of state)	Ranking for urban area change in 2000
Kentucky	135,200	0.5	24
Louisiana	164,200	0.5	23
Mississippi	108,600	0.4	30
Oklahoma	95,600	0.2	35
Tennessee	359,800	1.3	14
Texas	870,700	0.5	26
Mid-south total	2,078,700	0.5	
Kansas	90,400	0.2	38
Nebraska	41,200	0.1	44
North Dakota	13,000	0.0	45
South Dakota	12,900	0.0	47
Great Plains total	157,500	0.1	
Arizona	308,200	0.4	28
Colorado	165,200	0.2	33
Idaho	58,800	0.1	43
Montana	24,800	0.0	46
Nevada	132,300	0.2	37
New Mexico	129,500	0.2	39
Utah	90,200	0.2	40
Wyoming	12,000	0.0	48
Rocky Mountain total	920,900	0.2	
California	737,300	0.7	20
Oregon	119,100	0.2	36
Washington	275,700	0.6	22
Pacific Coast total	1,132,100	0.5	
Conterminous U.S. total	11,078,300	0.6	

The Motor City: Detroit, Michigan

In aggregate, the Southern Atlantic States had the largest percentage increase in urban land (1.8 percent), followed by the Northeastern States (1.5 percent). For all the Northern States, the increase was 1.0 percent. Regions with largest absolute urban growth were the South (5 million acres) and the North (4 million acres).

Most of the urbanization in Northern States occurred at the expense of agricultural (42.2 percent) and forested (37.0 percent) lands (Table 28, Fig. 59). Eleven of the 48 conterminous States had more than half of the total development occur within forests; of these, seven were Northern States, and two (Rhode Island and Connecticut) were at the top of the national list.



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

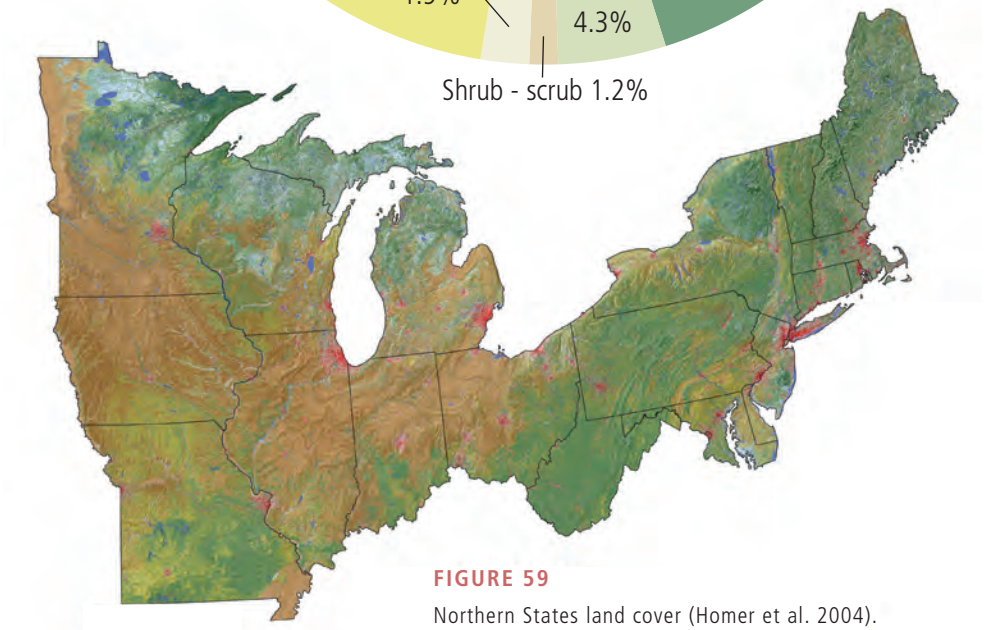


FIGURE 59

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

Table 28—Distribution of area converted to urban uses from 1990 to 2000, by selected cover types as they existed in 1992 (USGS 2003), for Northern States ordered from greatest to least proportion of forest land subsumed (Nowak et al. 2005).

State and region	Cover type					
	Forest[a]	Agriculture[b]	Other[c]	Developed[d]	Woody wetland[e]	Herbaceous wetland[f]
	Proportion of the total area subsumed by urbanization (percent)					
Rhode Island	64.8	5.7	0.8	19.0	7.9	1.9
Connecticut	64.1	11.5	0.9	16.2	5.8	1.7
Massachusetts	62.9	7.6	1.4	17.7	6.1	4.2
West Virginia	62.2	25.4	1.8	10.4	0.2	0.1
New Hampshire	61.3	10.2	1.3	20.7	4.2	2.4
Maine	54.8	7.7	1.3	26.1	3.7	6.3
New York	51.2	28.1	0.5	17.5	1.9	0.7
New Jersey	48.4	28.0	1.0	12.7	8.6	1.3
Maryland	43.5	40.7	2.6	9.5	2.7	0.9
Pennsylvania	42.7	45.5	1.4	9.7	0.4	0.2
Vermont	39.7	28.1	1.7	22.4	5.5	2.6
Ohio	31.6	50.8	0.4	14.3	2.3	0.6
Michigan	31.2	47.5	2.1	12.2	6.1	1.0
Missouri	28.6	44.7	6.5	19.0	0.8	0.3
Delaware	28.4	45.6	1.4	15.3	5.2	4.0
Wisconsin	18.3	62.0	2.2	14.5	2.2	0.6
Minnesota	17.7	52.4	1.1	17.6	3.7	7.4
Indiana	15.2	66.8	0.8	14.9	1.9	0.5
Illinois	15.2	64.8	1.8	15.2	2.4	0.7
Iowa	12.1	52.3	8.0	25.4	1.7	0.6
All North	37.0	42.2	1.6	14.5	3.3	1.3
Conterminous U.S.	33.4	32.7	14.0	15.1	3.5	1.4

[a]*Deciduous, evergreen or mixed forests; tree canopy accounts for 25 to 100 percent of the cover.*

[b]*Pasture/hay, row crops, small grains, or fallow (75 to 100 percent of the cover); or orchards/vineyards/other nonnatural woody (25 to 100 percent of the cover).*

[c]*Bare/rock/sand/clay, quarries/strip mines/gravel pits, transitional, shrubland (25 to 100 percent of the cover), or grasslands/herbaceous (natural/seminatural; 75 to 100 percent of the cover).*

[d]*Areas characterized by a high percentage (30 percent or more) of constructed materials (such as asphalt, concrete, or buildings), or vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes (75 to 100 percent of the cover).*

[e]*Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water*

[f]*Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water*

Preliminary projections of urbanization and forests, 2000 to 2050

Given the growth patterns of the 1990s, urban land is projected to expand substantially in the future—from 3 percent of the conterminous United States in 2000 to 8 percent in 2050, an increase in area greater than the State of Montana (Nowak and Walton 2005). By 2050, four States, all in the North, are projected to have more than half of their States classified as urban land: Rhode Island (71 percent urban), New Jersey (64 percent), Massachusetts (61 percent), and Connecticut (61 percent).

Although Northeastern States tended to have the highest percentage of forest land that is projected to be urbanized by 2050, Southern States are expected to have the highest acreage increases (Fig. 60): 2.2 million for North Carolina and 1.9 million for Georgia,

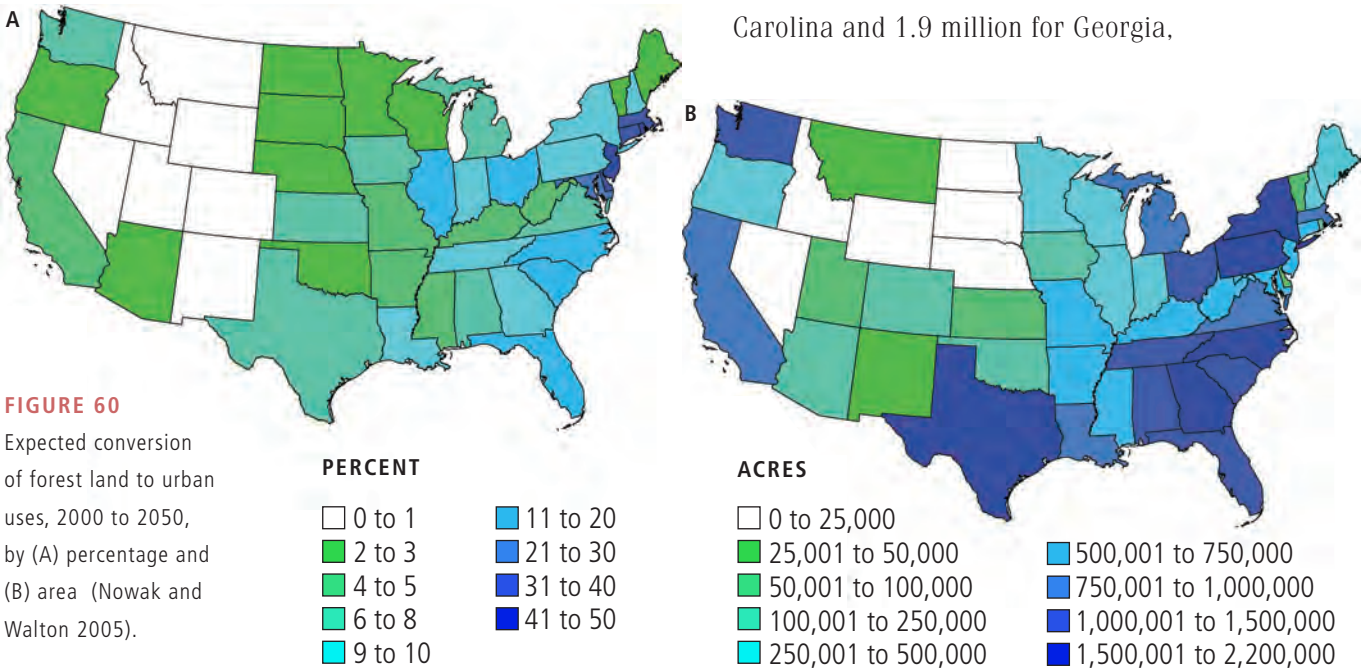


FIGURE 60
Expected conversion of forest land to urban uses, 2000 to 2050, by (A) percentage and (B) area (Nowak and Walton 2005).

followed by New York (1.7 million), Pennsylvania (1.6 million), and Texas (1.5 million). The projected total U.S. conversion of forest to urban land is about 29 million acres, an area approximately the size of Pennsylvania (Nowak and Walton 2005).

Tree and impervious cover in urban and community areas

Tree and impervious cover data in the conterminous United States are available through the National Land Cover Database using data from circa 2001 (Figs. 61 to 64). However, tree cover is likely underestimated in the database by about 9.7 percent nationally (Greenfield et al. 2009, Nowak and Greenfield 2010). To adjust for this potential underestimation, photo-interpretation of tree cover using GoogleEarth™ imagery (image dates from 2002 to 2009) was conducted for the conterminous United States (n=66,887 points) and for urban and community areas (n = 16,227 points). Based on this image interpretation, total tree cover in the North (Table 29) is 47 percent, ranging from 89 percent in New Hampshire to 10 percent in Iowa. Note that tree canopy cover includes trees on agricultural lands, on wetlands, in urban and community areas, and in other places that would not be classified as forest land. Thus, northern forest land, which has about 87 percent tree cover, is estimated to cover 42 percent of the land area (Fig. 1, Table 1) whereas 47 percent of all land is covered by trees (Figs. 61 and 63, Table 29).

In the North, tree cover averages 38 percent in urban areas, 37 percent in community land, and 39 percent in the combined urban or community category (Table 30). These values are higher than the national average because the Northern States are relatively heavily forested (Fig. 61) and urban tree cover is significantly

Table 29—Percent tree and impervious cover for Northern States based on photo-interpretation of GoogleEarth™ imagery.

State and region	Tree cover	Impervious cover
	(percent)	
New Hampshire	88.9	5.0
Maine	83.1	3.2
Vermont	81.5	1.9
West Virginia	81.4	2.0
Connecticut	72.6	7.7
Massachusetts	70.8	7.4
Rhode Island	70.3	10.9
Pennsylvania	65.8	4.6
New York	65.0	4.5
Michigan	59.5	4.1
New Jersey	57.0	12.1
Wisconsin	47.7	2.8
Maryland	42.8	6.1
Missouri	40.3	2.4
Ohio	39.9	5.5
Minnesota	34.8	2.2
Delaware	33.3	6.2
Indiana	25.7	3.7
Illinois	15.6	4.8
Iowa	10.4	3.0
All North	46.8	3.8

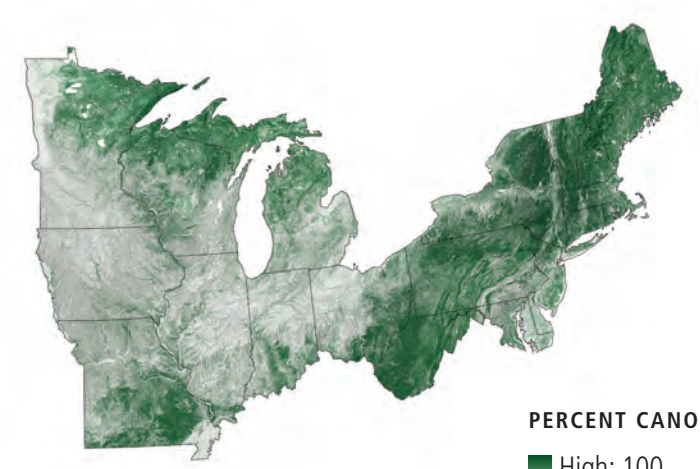


FIGURE 61
Tree canopy cover, 2001, (Homer et al. 2004).

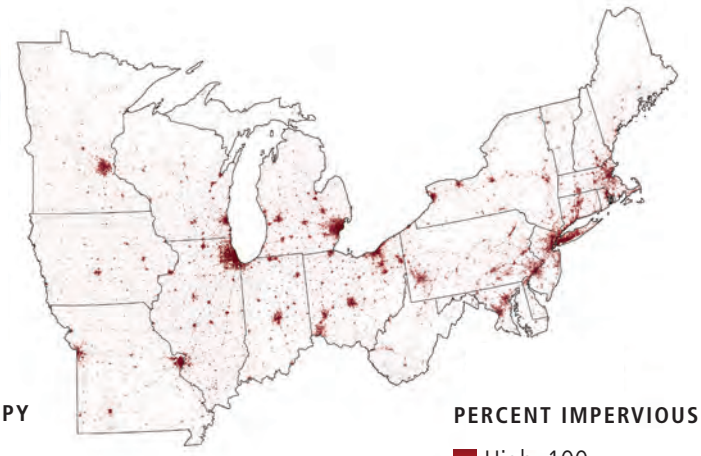


FIGURE 62
Impervious cover, 2001 (Homer et al. 2004).

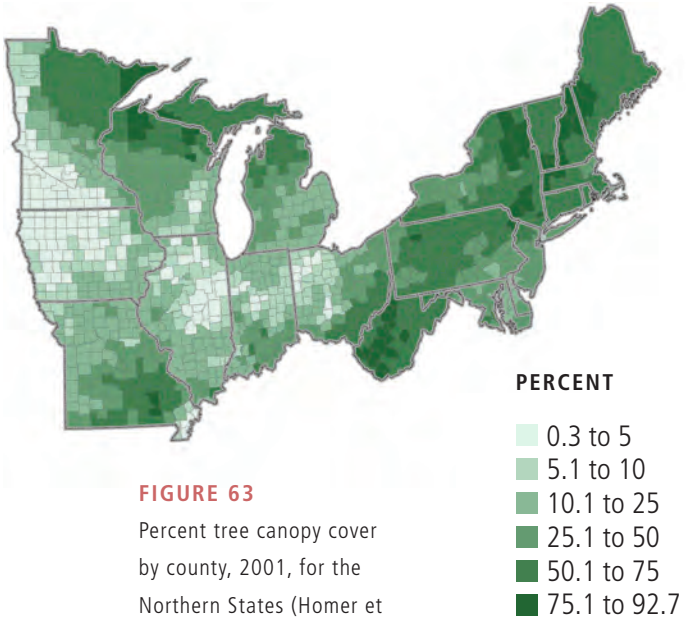


FIGURE 63
Percent tree canopy cover by county, 2001, for the Northern States (Homer et al. 2004).

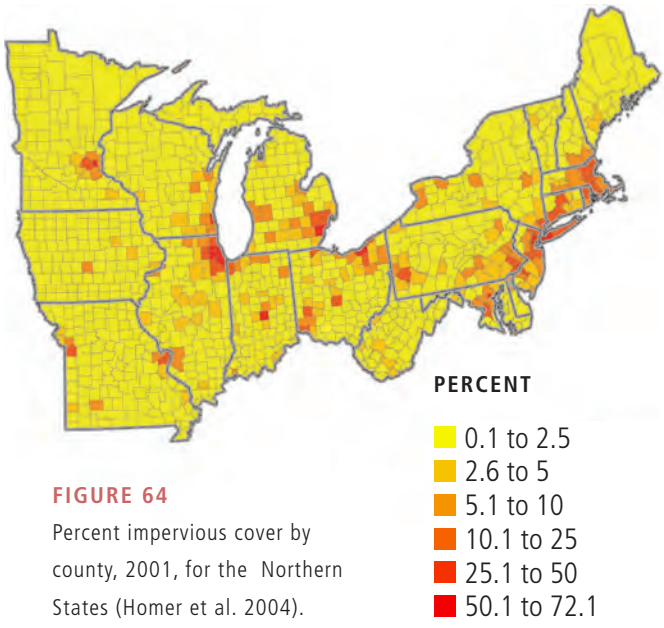


FIGURE 64
Percent impervious cover by county, 2001, for the Northern States (Homer et al. 2004).

affected by surrounding vegetation types (Nowak et al. 1996). Within urban areas in the Northern States, tree cover is highest in Connecticut (67 percent) and lowest in Indiana (22 percent). Within community areas, tree cover was highest in New Hampshire (67 percent) and lowest in Iowa (19 percent). Within the combined urban or community category, tree cover was highest in Connecticut (67 percent) and lowest in Iowa (19 percent). Figures 65 and 66 illustrate the distribution of tree cover and available space within urban or community land, based on NLCD 2001 data.

Impervious cover averages 24 percent in urban areas of the Northern States, 21 percent in communities, and 20 percent in the combined urban or community category (Table 30).

Table 30—Percent tree and impervious cover for urban, community, and urban or community land in the Northern States based on photo-interpretation of GoogleEarth™ imagery.

State and region	Urban land[a]		Community land[b]		Urban or community land	
	Tree cover	Impervious cover	Tree cover	Impervious cover	Tree cover	Impervious cover
	(percent)					
Connecticut	66.5	11.6	66.0	12.0	67.4	11.1
Massachusetts	64.5	16.7	60.9	16.1	65.1	14.5
New Hampshire	64.0	18.0	67.0	9.0	66.0	12.0
Maine	54.0	19.0	51.6	13.1	52.3	12.5
Rhode Island	54.0	26.0	40.0	36.0	51.0	24.0
Vermont	53.0	22.0	51.0	20.0	53.0	17.0
New Jersey	50.4	22.5	51.9	21.9	53.3	19.9
West Virginia	47.0	20.0	62.0	14.0	61.0	12.0
New York	41.2	27.4	41.1	24.3	42.6	22.4
Delaware	38.0	19.0	33.0	21.0	35.0	17.0
Michigan	34.6	31.5	34.0	29.0	35.0	26.8
Pennsylvania	34.0	24.6	45.0	18.6	41.0	19.1
Maryland	32.9	21.6	34.7	21.6	34.3	19.0
Missouri	31.1	22.0	29.2	18.3	31.5	18.0
Minnesota	31.0	24.1	33.8	13.2	34.0	13.3
Wisconsin	29.2	22.2	30.9	15.6	31.8	14.8
Ohio	29.0	27.1	31.0	28.1	31.5	24.5
Illinois	26.4	30.7	23.9	30.8	25.4	26.1
Iowa	24.0	27.0	18.8	20.4	19.0	19.5
Indiana	22.3	25.5	23.2	25.6	23.7	22.6
All North	38.2	24.4	36.8	21.4	39.0	19.7

[a]*All the territory, population, and housing units located within urbanized areas or urban clusters, each with a core population density of 1,000 people per square mile and with surrounding areas that have lower population densities (U.S. Census Bureau 2007).*

[b]*Places that have geopolitical boundaries (such as cities, towns, or unincorporated named places) that may include all, some, or no urban land within their boundaries.*

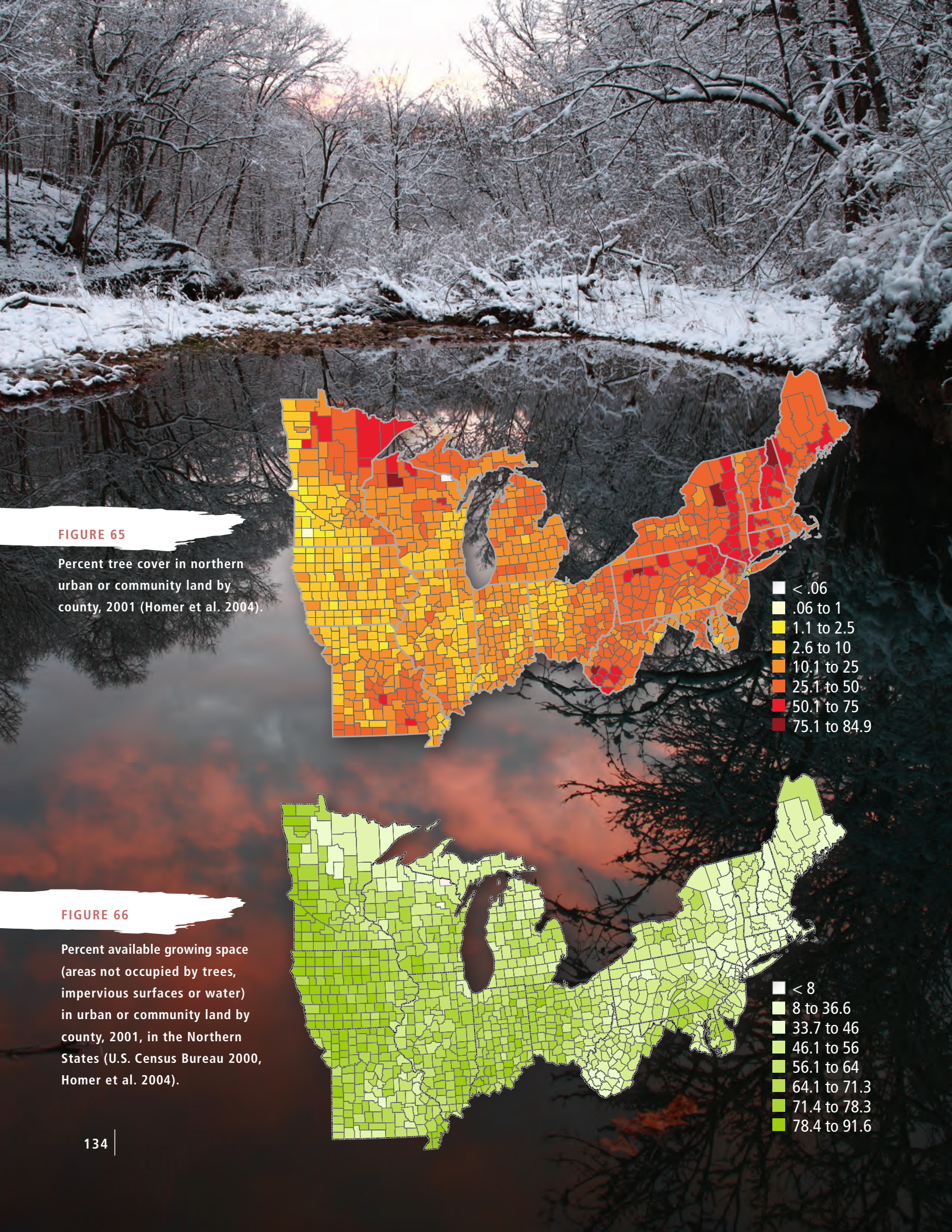


FIGURE 65

Percent tree cover in northern urban or community land by county, 2001 (Homer et al. 2004).

FIGURE 66

Percent available growing space (areas not occupied by trees, impervious surfaces or water) in urban or community land by county, 2001, in the Northern States (U.S. Census Bureau 2000, Homer et al. 2004).