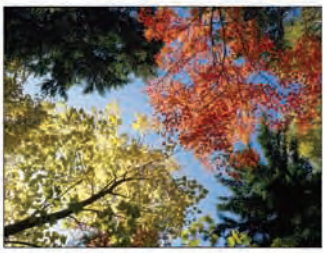

Sustainability Assessment Highlights for the Northern United States

United States
Department of
Agriculture

Forest Service

State and Private Forestry

Northeastern Area

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Constance A. Carpenter

Photo credits: All photos, unless otherwise indicated, were taken by Kenneth R. Dudzik, USDA Forest Service, Northeastern Research Station, Durham, NH.

Executive Summary

The *Sustainability Assessment Highlights for the Northern United States* provide a snapshot of today's forests and a baseline for tracking future trends. The highlights are based on a comprehensive assessment of forest sustainability organized according to an international system of criteria and indicators known as the Montreal Process. Criteria define broad categories of sustainability; indicators are specific measurements within each category. The criteria address biological diversity, the productive capacity of the forest, ecosystem health, soil and water resources, global carbon cycles, socioeconomic benefits from forests, and the legal, institutional, and economic systems that can impede or enable progress in sustainability.

This report covers the Northern United States—the 20 State region stretching from Maine to Minnesota, south to Missouri, and east to Maryland. The report was sponsored by the USDA Forest Service's Northeastern Area, State and Private Forestry and the Northeastern Area Association of State Foresters. It provides foresters, policymakers, landowners, and the public with information on factors that could threaten forest sustainability.

Conservation of Biological Diversity

Roughly 169 million acres of the 413 million acres of land in the Northern United States is forested. Forests were more extensive before European settlement than they are today; it is unlikely that the total forested acreage will reach historical levels again due to development trends. Forest and woodland communities are important components of the biological diversity of the Northern United States. Deciduous forests are more common than coniferous forests throughout most of the region; maple-beech-birch and oak-hickory are the most extensive forest cover type groups. No natural vegetative communities are known to have been eliminated since European settlement. Old growth forest is scarce, although the acreage of mature forest is increasing. The region hosts a number of naturally rare vegetative communities, as well as others that are imperiled due to human activities such as fire suppression and conversion of forest land to other land uses. The amount of urban forest—forest characterized by a high concentration of human influences—is increasing, but its biodiversity potential has not been comprehensively assessed.

Assessments of species at risk are incomplete, but the majority of native plants and animals evaluated in the Northern United States to date are doing well. Loss of habitat due to development is the most serious threat to forest species today; habitat modification and fragmentation are also concerns. A number of species that were once widespread are restricted to a portion of their former range; some plant and animal species are presumed to be extinct. Aquatic species are especially stressed. Various exotic species of plants, insects, and animals degrade forest habitat and compete with native species.

Public and private land conservation and management strategies are being used to ensure biodiversity conservation and maintenance in the Northern United States. Sound site management is an important part of genetic, species, and ecosystem diversity conservation.

Maintenance of Productive Capacity of Forest Ecosystems

Forests are a source of timber, fuelwood, and nonwood forest products. Roughly 93 percent of the forest land in the Northern United States is suited for timber production, although social and cultural constraints such as parcelization of forest land and changing landowner values reduce acreage available for harvest. Most timberland has average or above average productivity. Timberland acreage has recently begun to decrease because losses of forest land to development are no longer being offset by the conversion of agricultural land to forest land. Forest management practices can enhance timber productivity, as well as other values. Most timberland in the Northern United States is privately owned. Although the majority of private forest landowners do not intend to harvest timber on their land, they may ultimately do so. Those who do plan to harvest, however, own a greater proportion of private forest land.

The growing stock inventory in the Northern United States is at its highest level since the mid-1900's, and inventories indicate increases in growing stock volume are likely as stands across the region mature. Hardwoods account for a majority of the growing stock volume. Annual net growth exceeds removals for both hardwood and softwood tree species in all but one ecological region. The annual ratio of growth to removals is expected to decline in the future as both harvesting and the proportion of mature forest stands increases.

Information on the supply, growth, and removals of nontimber forest products are not readily available. It appears, however, that demand for nontimber products is increasing, and uncontrolled harvesting is impacting local populations of some species.

Maintenance of Forest Ecosystem Health and Vitality

The general health of the forest is difficult to assess at any one point in time, since it is dynamic and influenced by many factors. Measures of forest health include forest age and composition, trends in tree growth and mortality, tree crown condition, vulnerability to forest health stressors, and the condition of soil, water, and wildlife. Threats to forest health in the Northern United States are higher today than a century ago, largely because of human activities. Stressors that affect tree health include native and exotic insects and pathogens, invasive plants, impacts from severe weather, global climate change, and air pollution. Exotic insects and pathogens, in particular, pose a major threat in the Northern United States. Recent exotic insect introductions include the hemlock woolly adelgid, pine shoot beetle, Asian longhorned beetle, and emerald ash borer. Invasive plants are a mounting concern, as they colonize and become competitive with forest seedling regeneration. Increasing white-tailed deer populations affect forest sustainability and impact forest community composition and structure. Abiotic factors such as drought, ice storms, wind, fire, atmospheric ozone, and acidic deposition have caused significant damage. Combinations of stressors, such as exotic insects and pathogens along with drought, can lead to forest decline. Nonnative insects and pathogens pose a higher risk to forests than native species because of the lack of natural controls.

Conservation and Maintenance of Soil and Water Resources

The Northern United States has abundant water resources. Impacts on water chemistry, temperature, and sediment load are the result of a variety of factors, such as industrial,

agricultural, and urban pollution, development, atmospheric deposition, dam building, channelization, and forestry. Historic forest clearing left a legacy of eroded soils and stream sediment problems in parts of the region. Reforestation in these areas stabilized the soil; today the most heavily forested watersheds produce the highest quality surface and ground water. In other areas, decreases in watershed forest cover and losses of floodplain forests and wetlands, along with increases in urban and suburban development, have permanently altered the stream hydrology. Losses of riparian forests are highest in agricultural and urban areas, where the ability to buffer water bodies from the effects of nonpoint source pollution are most critical. Headwater streams are the most likely to have retained forest cover.

Many lakes, streams, wetlands, and estuaries in the Northern United States suffer from reduced biological integrity. Nearly all inventoried watersheds have some aquatic species at risk. v threaten aquatic resources and their use.

Current land use, forest management, and acid deposition are affecting soil properties and functions in localized areas and sites in the Northern United States; however, they have not resulted in changes in overall potential forest productivity. Timber harvest activities, road building, and lack of maintenance on roads and recreation trails are the most common contemporary sources of soil compaction and erosion on forest land. A relatively small proportion of eroded soil from these sources ends up in lakes and rivers.

Maintenance of Forest Contribution to Global Carbon Cycles

Growing forests naturally store carbon. The age and vigor of forest vegetation affects the rate of carbon sequestration in a forest ecosystem and the overall inventory of stored carbon. Trees are about 50 percent carbon and represent the most dynamic component of the forest ecosystem carbon pool, although the largest proportion of carbon is found in the soil. In the Northern United States, hardwoods account for a greater proportion of carbon than softwoods.

Changes in carbon inventory are affected by the rate of forest growth, harvest activity, and losses of forest cover due to conversion to other land uses, as well as fire or other natural disturbances. The carbon inventory in Northern U.S. forests is higher than in forests of any other region of the country. An underlying factor is that forests in the North are not harvested as heavily compared to growth as forests in the South and West.

Additional carbon is stored in wood that is processed or manufactured into products. The carbon stored in forests and forest products mitigates the amount of carbon released into the atmosphere, which may help delay global climate change.

Maintenance and Enhancement of Long-term Multiple Socio-economic Benefits to Meet the Needs of Societies

Forest land acreage increased over the last half of the 20th century but will decrease in the near future. This trend change will impact the provision of wood and nonwood products, wildlife habitat, recreational opportunities, forest-based communities, and the ability of forests to provide clean air and water. Wood product production and recreation are the two largest forest-based economic sectors in the Northern United States. Both total wood product consumption and consumption per capita are increasing, despite increased wood use

efficiency. The Northern United States leads the Nation in paper recycling, but recycled fiber is still underutilized.

Public land is an important asset for the recreation-based economy, as private landowners are becoming less willing to open their land to public use without economic incentives or liability protection. Opportunities for wilderness and backcountry recreation are decreasing while developed recreation sites are increasing. Recreation sites closest to urban centers get the most use.

The collection and production of nonwood products provides an important source of income in some locales. In many communities, the practice is strongly interwoven into local social and cultural traditions

Public investments occur in tree nurseries, tree planting, management, monitoring, education, and research. These funds are often used to leverage other State and private investments. Industry investments in paper and paperboard products have increased at a higher rate than investments in lumber and wood products.

Mechanization, globalization, and new technology have resulted in a decline in the number of timber industry jobs. Nevertheless, the timber industry contributes a relatively higher proportion of income and employment in the Northern United States than in other parts of the country. Paper manufacturers offer relatively higher wages than lumber or furniture manufacturers. Compensation for forestry workers varies across the region. Most States offer limited financial incentives to foresters to continue in field or service forestry for the course of their career. The safety of forest product jobs has increased steadily, but the death and injury rates are still higher than in most other professions. Manufacturing continues to be an important component of community economic stability; however, jobs in recreation, tourism, and other service sectors have replaced some wood manufacturing jobs.

Legal, Institutional, and Economic Framework for Forest Conservation and Sustainable Management

The Northern United States has a long-standing legal and institutional framework to use in supporting sustainability and negotiating a balance between public and private interests. The economic framework includes both incentives and disincentives to sustainability. As yet, there is no widely used systematic means of accounting for nonmarket services provided by natural resources; therefore, they continue to be undervalued and are often excluded from economic forecasts. Generally, analytical techniques and decisionmaking processes used to evaluate the benefits of forests and forestry do not account well for long timeframes and suffer from problems of uncertainty.

Private management decisions are often constrained by short-run considerations and market signals, while investments in forestry are long term. Trees take a relatively long time to grow, and the long-term welfare of landowners and society depends on the balance struck between current consumption and investment for future income. Decisions to invest in forests are influenced by policies that alter price, value, or use. Nonmarket factors tend to be ignored by the marketplace. The public, through government, bears the costs of ameliorating excesses or filling gaps in the incentives for resource management created by market forces and technological developments.

Public institutions in the Northern United States and nationwide are stressed by the rapid pace of social, demographic, and technological change combined with government budget cutting, restructuring, and personnel reductions.

Human-natural resource interactions are complex and there is still work to be done, especially in the arena of social and economic indicators. On a brighter note, private industrial organizations and associations are expanding their current policies and programs to achieve sustainability. In general, nongovernment educational and activist organizations are becoming better known through Internet technology and are more willing to work with public and industrial organizations using collaborative problem-solving approaches.

There have been improvements in forest management and in the production, marketing, and utilization of forest products and forest product substitutes to help conserve resources and mitigate environmental effects. Yet investment in research and technology is lagging behind the need and may jeopardize future progress.

State and Federal forestry agencies have monitoring programs that track forest type, age, distribution, and health throughout the Northern United States. This data is used to track trends important to sustainability.

Interrelationships Among Sustainability Criteria

The criteria and indicators are a useful tool for tracking sustainability trends and evaluating them in relation to one another. In doing so, several issues have surfaced that cut across multiple criteria in relation to resource values and uses—the size of the forested land base, the degree of forest fragmentation, the age of the forest, the spread of exotic and invasive insects, diseases, and plants, and land ownership patterns. These issues deserve attention in an effort to develop effective programs and policies to achieve sustainability in the Northern United States.

Introduction

The concepts of forest sustainability, sustainable forestry, and sustainable development embrace people's expectations that the Nation's forests, indeed *all* natural resources, should be used wisely to meet today's needs and be available to meet the needs of future generations. Sustainability embraces the desire to preserve the health of forest ecosystems in perpetuity and to meet human social, physical, and economic needs.

To address forest sustainability on a regional level, the USDA Forest Service's Northeastern Area, State and Private Forestry and the Northeastern Area Association of State Foresters sponsored a comprehensive assessment for the Northern United States (figure 1). The highlights presented here are excerpts from the assessment, which uses an international system of criteria and indicators of forest sustainability to describe forest conditions and important environmental, social, and economic trends that affect forests. This system is referred to as the Montreal Process.

The Montreal Process developed as a result of efforts following the 1992 Earth Summit. The United Nations Conference on Security and Cooperation in Europe sponsored an international seminar in Montreal, Quebec, to provide a forum for discussions on how to measure and track progress toward the goal of forest sustainability. These discussions provided the conceptual basis for subsequent regional and international initiatives to develop *criteria*, categories that provide a large-scale reflection of public values, and *indicators*, specific measurements within each criterion. The criteria address biological diversity, the productive capacity of the forest, ecosystem health, soil and water resources, global carbon cycles, socioeconomic benefits from forests, and the legal, institutional, and economic systems that can impede or enable progress in sustainability. The full list of criteria and indicators can be found in appendix A.

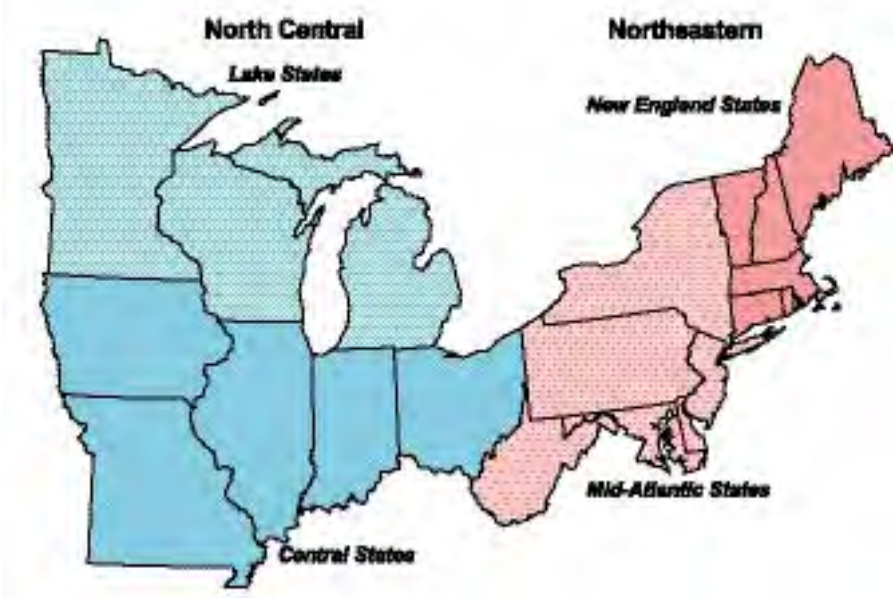


Figure 1. **The Northern United States.** The 20 States covered in this report may be subdivided into the multistate units shown for reporting purposes.

Criterion 1

Conservation of Biological Diversity

Criterion 1. Conservation of Biological Diversity

Biological diversity or **biodiversity** is the variety of life forms and processes that support them (The Keystone Center 1991). Conservation of biological diversity involves preserving the variety of species, the genetic variation within them, and the spectrum of communities and environments in which they occur (figure 2).

Genetic Diversity
The variation in genetic composition of individuals within and among species (e.g., variation with a population of rabbits).

Species Diversity
The variety of different species found in an area (e.g., the variety of species found in a prairie.

Ecosystem and Community Diversity
The variety of physical environments and biotic communities over a landscape (e.g., the variety of forests, grasslands, wetlands, and aquatic systems over a region).

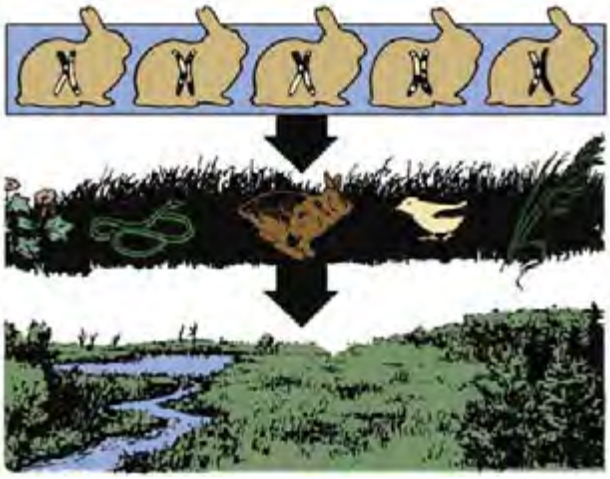


Figure 2. **Types of biological diversity.** There are three widely recognized types of biological diversity: genetic diversity, species diversity, and ecosystem diversity, which includes community diversity (Source: reproduced from Temple 1991 with author's permission).

Provinces of the Northern United States

Ecosystem diversity is evaluated in the assessment on a regional basis and by using maps of provinces coupled with inventories of forest cover and plant associations. Provinces are geographic units that span multiple States. Each province contains a unique mosaic of physical features, vegetation, and community structure that affect ecosystem processes influenced by both nature and people (figure 3).

- Comparisons with historical conditions can provide a baseline for measuring changes with the potential to affect ecosystem functions. Roughly 41 percent (169 million acres) of the 413 million acres of land in the Northern United States is forested (Hansen and others 1992). In 1630, shortly after European settlement began, forests covered roughly 73 percent of the area (Smith and others 2001), whereas at the beginning of the 20th century, forest cover had dropped to as little as 34 percent.
- Forest acreage is not distributed evenly across the Northern United States. Differences in natural potential can be tracked by province (figure 4) and related to the region's history.
- The mountainous Adirondack-New England Mixed Forest-Coniferous Forest-Alpine Meadow Province M212, the Laurentian Mixed Forest Province 212 that bounds Canada, and the mountainous Central Appalachian Broadleaf-Coniferous Forest-Meadow Province M221 had over 90 percent forest cover prior to European settlement. They have the highest percentages of forest cover across the Northern United States today—90, 71, and 70 percent, respectively (Irland 1998, McNab and Avers 1994, Minnesota 1992, Smith and others 2001, Wisconsin 1976).

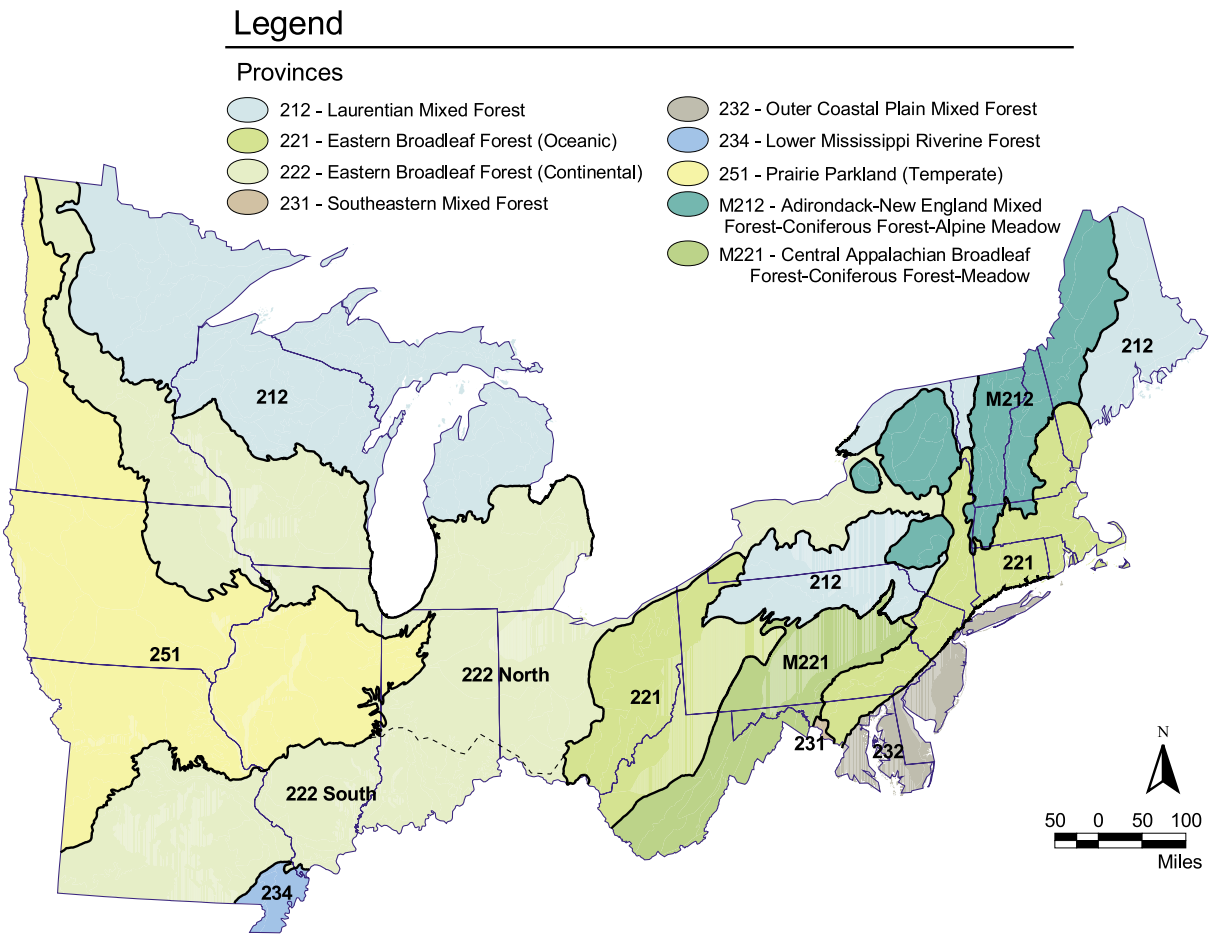


Figure 3. **Ecological units of the Northern United States.** Provinces on this map were developed by the USDA Forest Service using the National Hierarchical Framework of Ecological Units. Ecological units reflect the inherent biological capability of an ecosystem; therefore, they can be used to establish reference environmental conditions against which the predicted effects of management activities can be compared (Source: adapted from Keys and others 1995).

- The Eastern Broadleaf Forest (Oceanic) Province 221 and the Outer Coastal Plain Mixed Forest Province 232 were colonized early in American history and continue to contain the most populated areas of the country. These provinces were predominantly forested when the settlers arrived and today have 54 and 41 percent forest cover, respectively. All but the most unproductive and inaccessible forest land was converted to farm use while the forest resources were heavily exploited for fuelwood, charcoal, local construction, industry, and export. The extent of forest recovery is less in these two provinces than in provinces to the north because the climate and soils are more favorable for agriculture and suitable for development (Foster 1992, McNab and Avers 1994, Shands and Healy 1977, Smith and others 2001).
- Forest was the most common land cover in the Eastern Broadleaf Forest (Continental) Province 222 before European settlement. Today the rugged southern half of the province (222S) is roughly 40 percent forested, while the glaciated northern portion (222N) is only 19 percent forested. Colonization into this province followed major river corridors and lagged over a century behind the East. Much of the land cleared for farming remains in

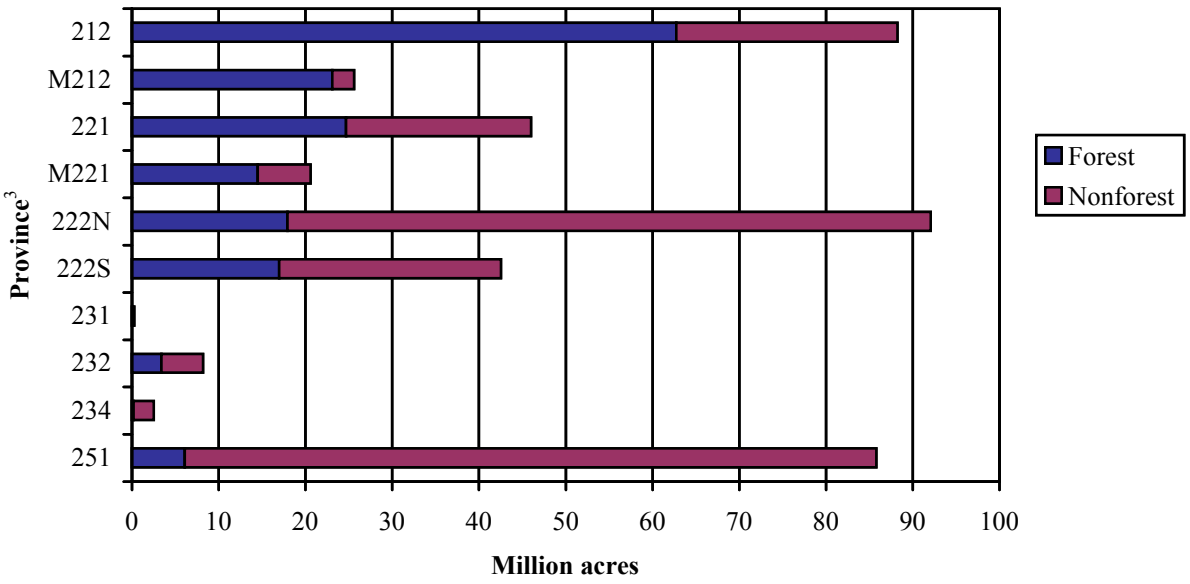


Figure 4. **Amount of forested and nonforested land in each province of the Northern United States**[1] (USDA Forest Service 1999a[2]).

[1]Does not include 2,594,600 acres of Adirondack and Catskill Preserves (NY).

[2]Inventory follows methods in Hansen and others 1992.

[3]Amounts of forest land in provinces 231 and 234 and nonforested land in province 231 are too small to appear on graph but do not equal 0.

agricultural use today, although some marginal, often heavily eroded cropland has reverted to forest cover or was reclaimed by aggressive conservation programs (McNab and Avers 1994, Shands and Healy 1977, Smith and others 2001).

- Prairie dominated the presettlement landscape in the Prairie Parkland (Temperate) Province 251. Then, as today, forests were often found in drainage ways and bottomlands, though upland forests and savannahs also existed. Most of the prairie and adjacent forest land has been converted to and retained as cropland or pastureland (Kuchler 1964, McNab and Avers 1994, Shands and Healy 1977, Smith and others 2001).
- The Lower Mississippi Riverine Forest Province 234 lost much of its bottomland forest to agriculture. The land that is forested today is highly valued for its contribution to plant and animal diversity (McNab and Avers 1994, Smith and others 2001).

Forest Cover Types

Forest cover types are groupings of trees named after the predominate tree species. Sixty-four forest cover types have been identified in the Northern United States (box 1). These forest cover types are divided into nine major forest cover type groups: white-red-jack pine, spruce-fir, loblolly-shortleaf pine, oak-pine, oak-hickory, oak-gum-cypress, elm-ash-red maple, maple-beech-birch, and aspen-birch (figure 5).

- The most extensive forest cover type groups in nearly every province are oak-hickory and maple-beech-birch. They each occupy over 50 million acres of forest land; together they account for more than 60 percent of the total forested land area in the Northern United States (table 1).

Box 1. **Forest cover type groups in the Northern United States**. Nine major forest cover type groups include the 64 forest cover types identified in the Northern United States (USDA Forest Service 2001).

Aspen-Birch Group
- Aspen
- Paper birch
- Gray birch
- Balsam poplar

Elm-Ash-Red Maple Group
- Black ash/American elm/red maple
- River birch/sycamore
- Cottonwood
- Willow
- Sycamore/pecan/American elm
- Sugarberry/hackberry/American elm/green ash
- Silver maple/American elm
- Red maple/lowlands
- Cottonwood/willow

Loblolly-Shortleaf Pine Group
- Loblolly pine
- Shortleaf pine
- Virginia pine
- Table-mountain pine
- Pond pine
- Pitch pine

Maple-Beech-Birch Group
- Sugar maple/beech/yellow birch
- Black cherry
- Cherry/ash/yellow-poplar
- Hard maple/basswood
- Elm/ash/locust
- Red maple/uplands

Oak-Gum-Cypress Group
- Swamp chestnut oak/cherrybark oak
- Sweetgum/Nuttall oak/willow oak
- Overcup oak/water hickory
- Atlantic white cedar
- Baldcypress/water tupelo
- Sweetbay/swamp tupelo/red maple

Oak-Hickory Group
- Post/blackjack oak
- Chestnut oak
- White oak/red oak/hickory
- White oak
- Northern red oak
- Yellow-poplar/white oak/northern red oak
- Sassafras/persimmon
- Sweetgum/yellow-poplar
- Scarlet oak
- Yellow-poplar
- Black walnut
- Black locust
- Chestnut oak/black oak/scarlet oak
- Red maple/oak
- Mixed upland hardwoods

Oak-Pine Group
- White pine/northern red oak/white ash
- Eastern redcedar/hardwood
- Shortleaf pine/oak
- Virginia pine/southern red oak
- Loblolly pine/hardwood
- Other oak/pine

Spruce-Fir Group
- Balsam fir
- White spruce
- Red spruce
- Red spruce/balsam fir
- Black spruce
- Tamarack (eastern larch)
- Northern white cedar

White-Red-Jack Pine Group
- Jack pine
- Red pine
- White pine
- White pine/hemlock
- Hemlock

Urban Forest

Urban forests are forested ecosystems characterized by a high concentration of human influences. Metropolitan areas or urban areas are usually used to approximate the extent of urban forest since ecological maps are not available. Metropolitan area and urban area boundaries are defined by the U.S. Bureau of the Census and the Office of Management and Budget (USDC Bureau of the Census 1997, USDC Economic and Statistics Administration 1994).

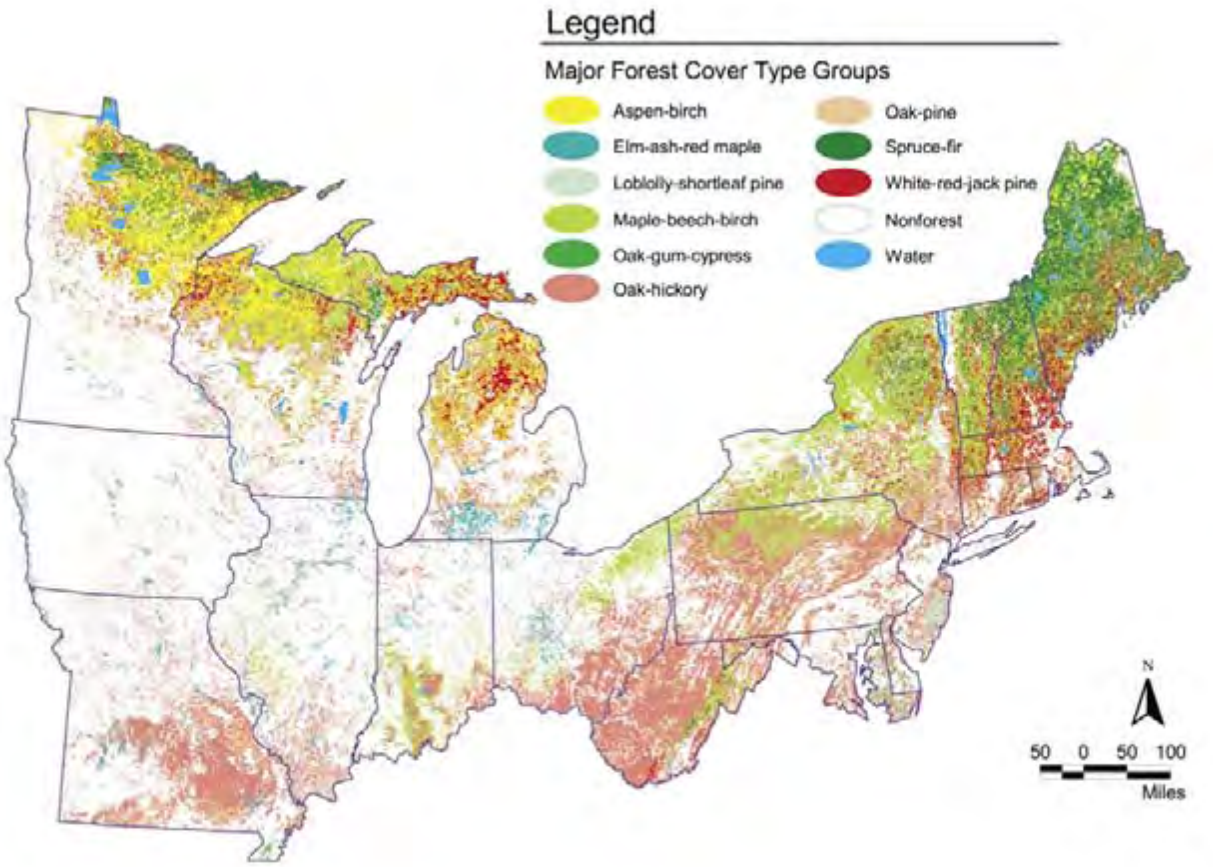


Figure 5. **Forest cover type groups in the Northern United States** (Source: developed by the USDA Forest Service Forest Inventory and Analysis Group using AVHRR [Advanced Very High Resolution Radiometer] data).

Table 1. **Amount of forest land by forest type group and province in the Northern United States**[1,2]. The most extensive cover type groups are oak-hickory, maple-beech-birch, aspen-birch, and spruce-fir (USDA Forest Service 1999a[3]).

Province	Oak-hickory	Maple-beech-birch	Aspen-birch	Spruce-fir	Elm-ash-red maple	White-red-jack pine	Oak-pine	Loblolly-shortleaf pine	Oak-gum-cypress	Non-stocked	Total
	Thousand acres										
212	5,353	20,623	14,226	12,419	3,626	5,622	303	30	28	344	62,575
M212	842	11,878	1,531	3,972	180	1,825	226	5	6	25	20,489
221	12,622	6,682	472	88	1,500	1,921	923	369	38	51	24,666
M221	10,046	2,849	69	83	169	445	525	269	11	21	14,487
222N	6,035	6,093	1,389	192	2,881	975	107	62	118	86	17,938
222S	11,767	1,978	0	0	1,272	58	1,088	597	158	50	16,968
231	66	8	0	0	0	0	0	0	0	0	74
232	1,603	60	6	0	136	6	483	849	235	11	3,388
234	45	18	0	0	52	0	0	0	31	23	169
251	3,223	1,341	28	0	1,258	24	39	33	93	28	6,069
Total	**51,604**	**51,533**	**17,726**	**16,753**	**11,074**	**10,883**	**3,694**	**2,213**	**719**	**639**	**166,838**

[1]Does not include 2,594,600 acres of Adirondack and Catskill Preserves (NY).

[2]Values in the columns may not add up to the totals due to rounding.

[3]Inventory follows methods in Hansen and others 1992.

- Metropolitan areas encompass roughly 34 percent of the land area in the Northern United States. Urban areas, the most densely populated core of metropolitan areas, occupy nearly 6 percent of the Northern United States land base.
- A conservative estimate by Dwyer and others (2000) indicates that nearly 26 percent of the forest land in the Northern United States is located in metropolitan areas (figure 6).

Natural Communities

A **natural community** is comprised of all species, including trees, shrubs, herbs, ferns, mosses, algae, and other plants; animals; and organisms that are not plants or animals such as fungi, protozoa, and bacteria.

Figure 6. **Forest cover in metropolitan areas.** Most metropolitan areas in the Northern United States contain areas with over 40 percent forest cover (Dwyer and others 2000).

The State Natural Heritage Programs and The Nature Conservancy cooperatively developed a taxonomy of terrestrial plant communities called the U.S. National Vegetation Classification (US NVC) (Anderson and others 1998, Grossman and others 1998). The **association** is the most detailed level of classification. US NVC associations are categorized into seven broad taxonomic classes: forest, woodland, shrubland, dwarf-shrubland, herbaceous, nonvascular, and sparse vegetation.

- The Northern United States contains 787 associations, 17 percent of the 4,684 associations identified nationally. The distribution of associations among taxonomic classes in the Northern United States is similar to the national average. Over half of the known associations are classified as forest or woodland (table 2).

Table 2. **US NVC natural and seminatural[1] associations by class[2]**. Forest and woodland associations comprise over half of those found in the Northern United States.

Class	Associations			
	Northern United States		United States	
	Number	Percent	Number	Percent
Forest	301	38	1,583	33
Woodland	111	14	849	18
Shrubland	69	9	763	16
Dwarf-shrubland	25	3	135	3
Herbaceous	225	29	1,247	27
Nonvascular	5	1	11	< 1
Sparse vegetation	51	6	96	2
Total	**787**	**100**	**4,684**	**100**

[1]Natural and seminatural communities as distinguished from planted/cultivated types.

[2]Source: TNC 1998. Numbers are subject to change as current inventory results are posted to the database.

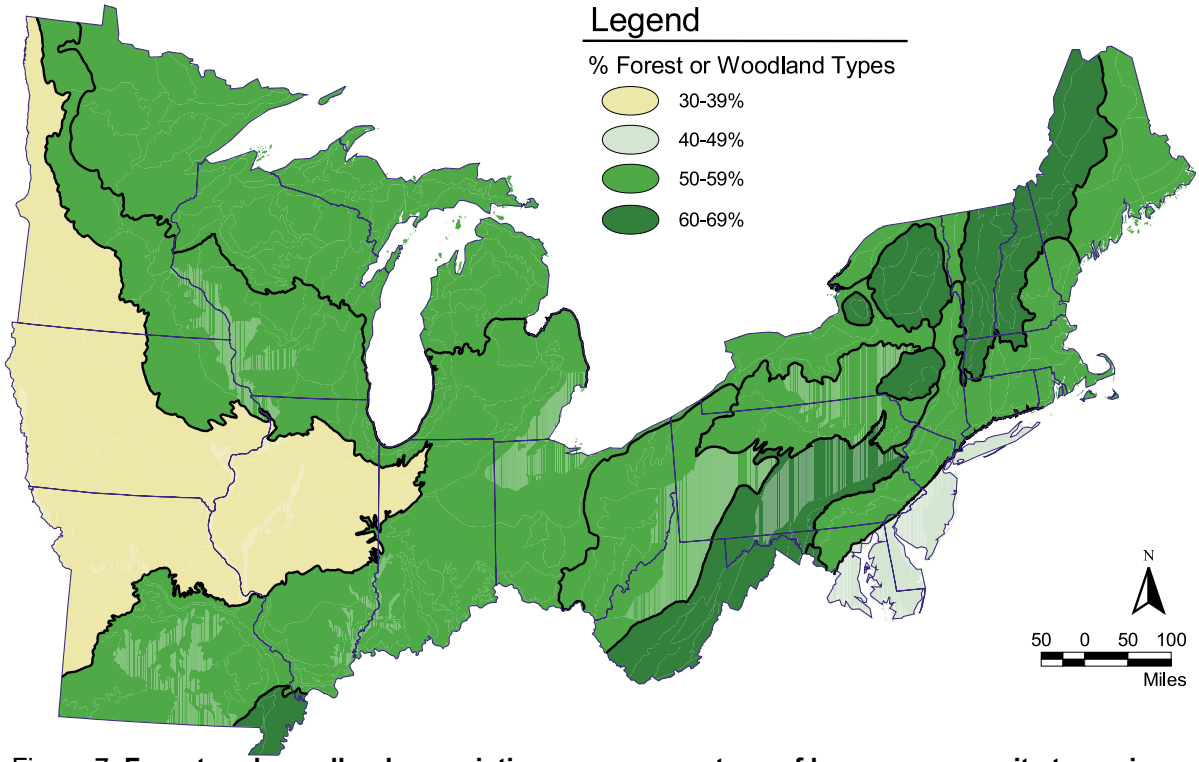


Figure 7. **Forest and woodland associations as a percentage of known community types in each province.** Provinces are displayed in figure 3 (Source: TNC 1998).

Forest and woodland associations add richness to the suite of communities found in each province. Between 34 and 65 percent of known communities in each province are forest or woodland (figure 7). The highest percentages of forest and woodland types occur in the Appalachian Mountains, the lowest in the prairies.

- Of the 787 associations found in the Northern United States, 309 or 39 percent are classified as globally rare. Rare forest and woodland associations represent 17 percent of the total number of associations in the Northern United States and 43 percent of those ranked as rare (table 3).
- No natural communities are known to have been eliminated to date.
- The reasons for rare status vary by natural community and location. Many rare forest and woodland communities in the Northern United States are naturally small and historically of limited extent. Some occur at high elevations, others along the Atlantic coast, and in barrens and bluffs. Other communities that were once common or extensive, however, have been affected by human activities. Many prairies, wetlands, and floodplain forests have been converted to agricultural or urban uses, while fire suppression limits regeneration in communities with fire-dependent trees, such as pitch pine and oak.

Table 3. **US NVCS rare associations in the Northern United States by class**. Forest and woodland associations represent 43 percent of associations ranked as rare (TNC 1998).

Class	Rare associations	
	Number	Percent
Forest	74	24
Woodland	59	19
Shrubland	27	9
Dwarf-shrubland	12	4
Herbaceous	121	39
Nonvascular	2	< 1
Sparse vegetation	14	5
Total	**309**	**100**

Forest Age and Successional Stage

Knowledge of forest type and successional stage is important for biodiversity management because the communities of plants and animals that inhabit any given site vary over time. While there is no direct inventory of the extent of forest cover in the Northern United States by succession stage, the USDA Forest Service has tracked changes in age through its Forest Inventory and Analysis Program.

- An estimated 76 percent of forest stands in the Northern United States are less than 80 years old, and less than 2 percent of stands are more than 120 years old. Mixed age stands comprise 9 percent of those inventoried, although the actual acreage is greater because mixed aged stands were assigned to specific age groups in protocols followed for the North Central States (table 4).

Table 4. **Acreage of forest land by age class and forest type in the Northern United States**[1,2] (USDA Forest Service 1999a[3]).

Age group	Oak-hickory	Maple-beech-birch	Aspen-birch	Spruce-fir	Elm-ash-red maple	White-red-jack pine	Oak-pine	Loblolly-shortleaf pine	Oak-gum-cypress	Non-stocked[4]	Total
	Thousand acres										
0–40	19,212	16,271	8,887	5,468	5,258	4,108	1,371	1,061	265	549	62,450
41–80	21,226	20,267	7,166	5,622	4,180	4,112	1,469	612	274	34	64,961
81–120	7,072	7,337	863	2,842	1,076	1,149	295	52	60	17	20,764
121–160	599	966	66	825	160	91	0	4	3	3	2,716
160+	19	93	9	140	14	9	0	0	0	0	283
Mixed	3,476	6,599	735	1,856	387	1,414	559	485	117	37	15,664
Total	**51,604**	**51,533**	**17,726**	**16,753**	**11,074**	**10,883**	**3,694**	**2,213**	**719**	**639**	**166,838**

[1]Does not include 2,594,600 acres of Adirondack and Catskill Preserves (NY).

[2]Values in the columns may not add up to the totals due to rounding.

[3]Inventory follows methods in Hansen and others 1992.

[4]Timberland less than 10 percent stocked with all live trees.

- Natural disturbance, timber harvesting, and natural aging are factors that move forests to early successional stages. Types of natural disturbance common across the Northern United States include individual tree falls, fires, and ice storms. Larger fires tend to occur in oak-hickory forests and on pinelands with sandy soils throughout the region. Blowdowns and hurricanes are most common along the Atlantic coast and in New England. Tornadoes occur most commonly in the Midwest. Timber harvesting occurs most often on stands between 60 and 120 years of age, although aspen-birch stands are harvested closer to 60 years, while maple-beech-birch stands are harvested closer to 100 or 120 years.
- The majority of trees in urban areas are small in diameter, though there are some differences in age by land use. For example, institutional and residential lands may have more large trees than industrial and agricultural areas since groundskeepers and residents may work to retain large trees and discourage understory development. Vacant urban lots in the region tend to regenerate to trees naturally over time (Dwyer and others 2000).

Old Growth

Definitions of old growth abound, ranging from mature virgin forested areas to stands managed for old growth characteristics regardless of degree of human intervention. Some definitions focus on the age or size of the trees, others on the age and naturalness of the forest community. Nearly all identify important structural characteristics, including both live and dead vegetation and soil characteristics. The biological diversity associated with old growth depends on the ecological potential of the forested sites and the effects of the natural disturbance regime on the age class structure. For example, spruce-fir forests of all successional stages exhibit less species diversity than maple-beech-birch forests.

- There are varying estimates of how much old growth remains; it is generally believed that there is more than has been reported to date. Davis (1996) identified 1,296,000 acres of old growth in the Northern United States—0.77 percent of the total amount of forested land. This figure includes what Davis calls primary or original forest sites undisturbed by humans or with limited logging or grazing. Davis' definition emphasizes old trees as opposed to big trees, which has resulted in increases to 1993 estimates (Davis 1993).
- National forests in the East were established when the Federal government acquired cutover forest land and spent agricultural land (Shands 1991, Shands and Healy 1977). Therefore, only a limited number of acres on these forests are believed to contain old growth in the sense of primary forest unmodified by humans. Out of necessity, the focus of the national forests has been to plan for future old growth. Some 1.4 million acres, roughly 11 percent of national forest lands in the Northern United States, have been allocated to old growth in existing forest plans (Tyrrell 1996). This allocation is in addition to any old growth that exists on land designated as Wilderness or Research Natural Areas.

Conservation of Ecosystem Diversity

The International Union for the Conservation of Nature (IUCN) defines a protected area as "an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means" (IUCN 1994, p. 6). Protection can range from strict protection to management in conjunction with other uses. IUCN categorizes public lands based on management objectives in the authorizing legislation (table 5).

- The 11.9 million acres of national forest land in the Northern United States are managed for multiple objectives. These objectives cross the full range of IUCN categories.
- Roughly 5 percent (8.2 million acres) of forest land in the Northern United States is reserved from timber utilization by statute or administrative regulation by some level of government. The majority of this reserved forest land is located in Provinces M212 and 212 (figure 8).
- The majority of reserved forest land in the Northern United States is in the oak-hickory and maple-beech-birch cover types (figure 9). Roughly 76 percent of the reserved lands are less than 40 years old. Mixed aged stands account for just over 2 percent of the reserved land and about 0.5 percent of stands are over 120 years old (USDA Forest Service 1999a).

Table 5. **Northern United States land in International Union for the Conservation of Nature protected area categories** (IUCN 1994).

	Protected area category	Objective	Examples[1]	Acres[1]
I.	Strict nature reserve or wilderness area	Manage outstanding or representative ecosystem for science or wilderness character	Research Natural Areas, National Forest Wilderness Areas (e.g., Boundary Waters Canoe Area Wilderness, MN)	1,411,984
II.	National park	Manage for recreation compatible with ecosystem protection	National Parks (e.g., Isle Royale, MI), State Parks (e.g., Baxter, ME)	2,134,563
III.	Natural monument	Manage for unique natural/cultural features	National Natural Landmarks (e.g., Canaan Valley, WV)	373,025
IV.	Habitat/species management	Manage for specific habitats or species	National Wildlife Refuges (e.g., Crab Orchard, IL)	1,043,259
V.	Protected landscape/ seascape	Manage for landscape/seascape conservation and recreation	State Parks (e.g., Adirondack, NY; Holyoke Range, MA), National Reserves (e.g., Pinelands, NJ)	9,955,202
VI.	Managed resource protected area	Manage unmodified natural systems for biodiversity and sustainable flow of natural products	National Forests (e.g., Hoosier, IN), State Forests (e.g., Garrett, MD)	11,625,788

[1]Source: UNEP-WCMC 2002

Private landowners and public land managers can contribute to forest ecosystem diversity by managing their lands in ways that maintain their inherent ecological potential and provide habitat for wildlife, and by establishing land use patterns that allow for the movement of wildlife species across the landscape.

- Land trusts play an important role in biological diversity conservation. They operate at local, regional, and national scales. The *1998 National Directory of Conservation Land Trusts* listed a total of 831 local land trusts operating in the Northern United States (Land Trust Alliance 1998). These local land trusts protected 1,705,287 acres through 1998, including 476,122 acres owned by the trusts, 682,900 acres under easement, and 546,265 acres acquired and transferred to a government agency (figure 10). Of these trusts, 250 listed conservation of rare species habitat as one of their conservation objectives.

Lands in the public domain are expected to form the base for nearly all protected areas or reserve systems. It is common, however, for land trusts and large landowners to dedicate some lands to the protection of species and ecosystems. Some private landowners enter into agreements such as conservation easements—legal contracts that provide some compensation to landowners for the dedication of their land or property rights—with public or private organizations. In addition, some contribution to reserves is often a part of forest certification recommendations for large landholders.

Fragmentation

Fragmentation is the breaking up of large and continuous ecosystems, natural communities, and habitats into smaller areas surrounded by altered or disturbed land or aquatic substrate.

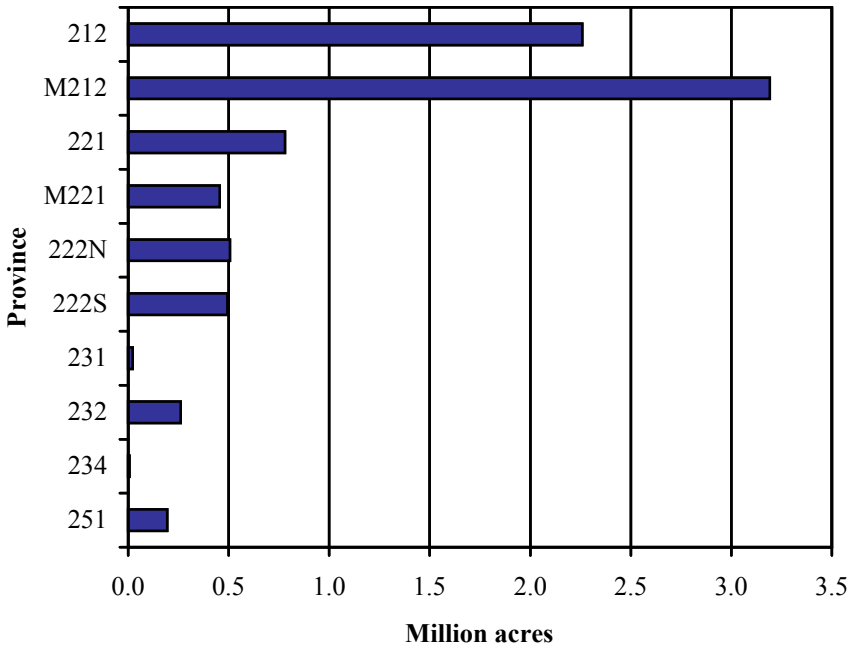


Figure 8. **Reserved forest and by province** (USDA Forest Service 1999a[1]).

[1]Inventory follows methods in Hansen and others 1992.

- The cause of fragmentation of greatest concern today is the permanent and long-term conversion of forest land to development. According to the USDA Natural Resources Conservation Service (2001), nearly 3.7 million acres of forest land in the Northern United States were converted to developed land between 1982 and 1997, representing 45 percent of the nearly 8 million acres of land developed during that period (figure 11). Pennsylvania (620,500 acres), Michigan (372,900 acres), and Massachusetts (367,800 acres) had the highest losses to development; Iowa (14,800 acres) had the lowest.

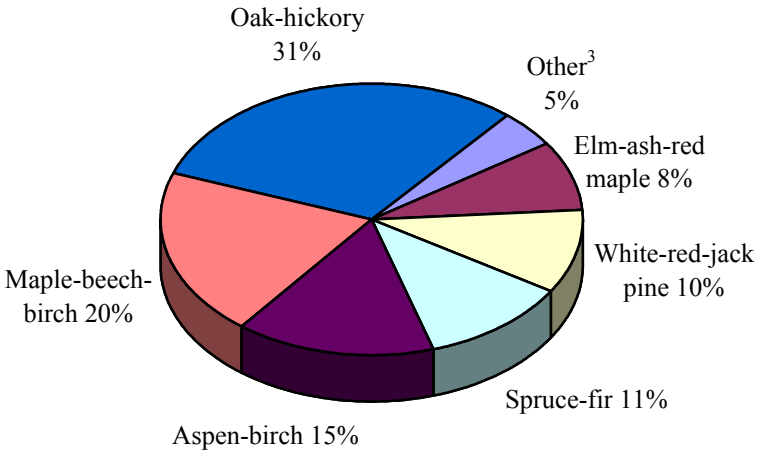


Figure 9. **Reserved forest land by forest cover type in the Northern United States**[1]. The oak-hickory and maple-beech-birch forest cover types comprise over half of the reserved forest land in the Northern United States (USDA Forest Service 1999a[2]).

[1]Does not include 2,456,000 acres of reserved timberland and 138,600 acres of reserved other forest land in the Adirondack and Catskill Preserves (NY).

[2]Inventory follows methods in Hansen and others 1992.

[3]Includes oak-gum-cypress, oak-pine, and loblolly-shortleaf pine.

- Suburbanization is the primary cause of deforestation on rural landscapes in the Northern United States today, surpassing conversion to agriculture (Zipperer and others 1990). Urban and suburban expansion reduces

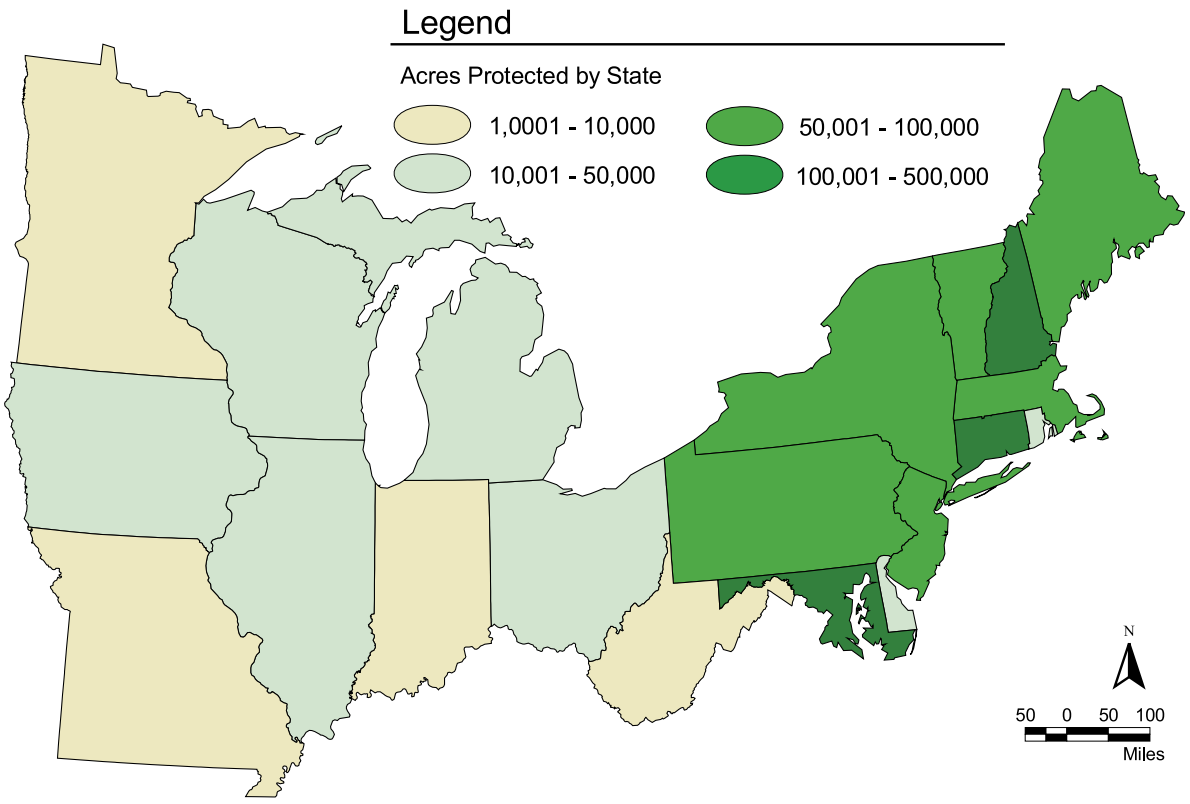


Figure 10. **Acres protected by land trusts through 1998.** Land trusts play an important role in

the amount of land available for the production of forest goods and alters associated environmental services. Habitat deforestation is considered by many to be the most serious threat to biological diversity and a primary cause of species decline (DeGraaf and Healy 1990, Wilcove and others 1986).

Species Diversity

Species richness is a measure of biological diversity based on the total number of species inhabiting a defined area. The number of species is not the only consideration in biodiversity management. For example, a rare species will attract more attention than a common species, and native species are generally preferred over nonnative species.

- Roughly one-fifth of the known species, including 13 major groups of plants and animals in the United States, have been studied in sufficient detail to assess their global conservation status (TNC and ABI 2000). The majority of native plants and animals in the Northern United States are secure or apparently secure (figure 12). Twenty-five Northern United States species are presumed to be extinct or possibly extinct: 6 are birds, 7 are fish, 8 are freshwater mussels, and 4 are flowering plants.

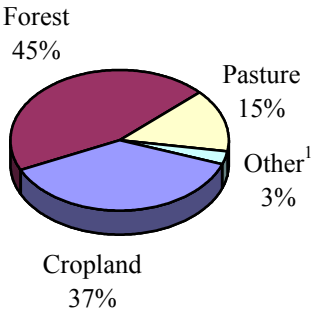
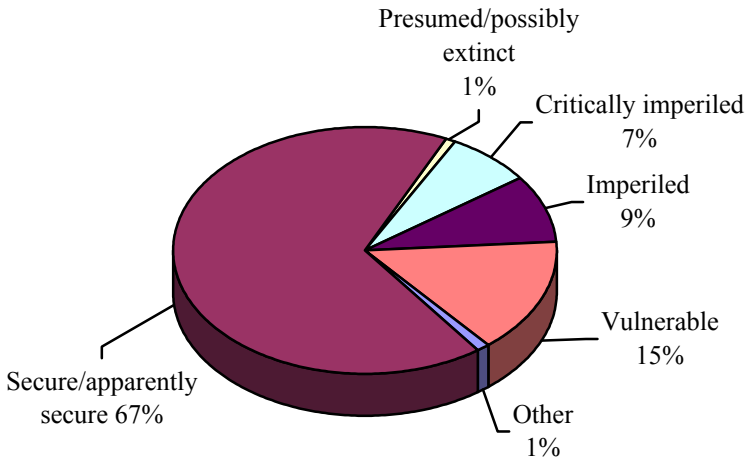


Figure 11. **Land developed, 1982–1997**. About 45 percent of the nearly 8 million acres developed in the Northern United States was forest land (USDA NRCS 2001).

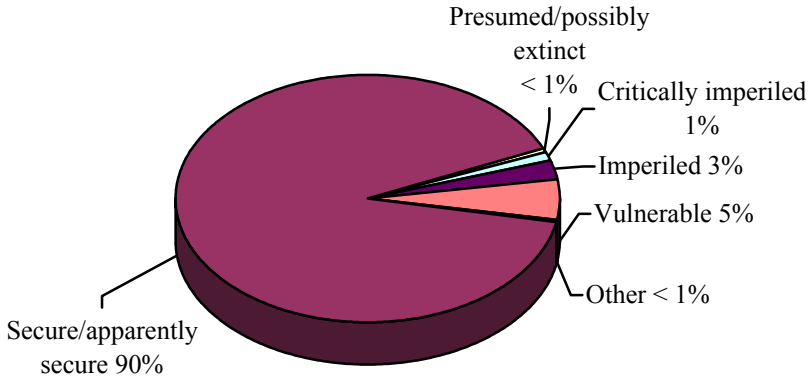
[1]Includes rural land, rangeland, water areas, and Federal land.

United States



Based on 2,536 vertebrates, 1,795 invertebrates, and 16,108 plants (TNC 1997).

Northern United States



Based on 1,169 vertebrates, 725 invertebrates, and 3,975 plants (TNC and ABI 2000).

Presumed extinct	Not located despite intensive searches
Possibly extinct	Of historical occurrence; still some hope of rediscovery
Critically imperiled	Typically 5 or fewer occurrences or 1,000 or fewer individuals
Imperiled	Typically 6–20 occurrences or 1,000–3,000 individuals
Vulnerable	Typically 20–100 occurrences or 3,000–10,000 individuals
Apparently secure	Uncommon but not rare; some cause for long-term concern; usually more than 100 occurrences and 10,000 individuals
Secure	Common; widespread and abundant

Figure 12. **Global conservation status of plants and animals.** The majority of native plants and animals in the United States and in the Northern United States are secure/apparently secure.

- Nonnative (exotic) species are often opportunistic and aggressive, and may prey on native species. Naturalized exotics change community species composition and may decrease the natural diversity of native wildlife (Harty 1993). Examples of nonnative birds that have been introduced into the Northern United States include the house sparrow, the European

starling, and the ring-necked pheasant (Ehrlich and others 1988).

Opportunities to conserve wildlife species include creating wildlife habitats and enhancing existing habitats through forest and landscape planning and management.

Forest-Dependent Species

Many wildlife species that live in forests can survive in nonforested habitats. **Forest-dependent species** require the use of forested habitat at some point in their life cycle.

- Nationally, the USDA Forest Service reported that at least 90 percent of the bird, amphibian, and fish species in the country and at least 80 percent of mammal and reptile species can be sighted on forested land, though they may or may not be dependent on that habitat for survival (USDA Forest Service 1997a).
- There is no definitive list of forest-dependent species in the Northern United States.
- The ovenbird and the American marten are examples of species that require forested habitat during their entire life cycle (DeGraaf and Rudis 1986).

Endangered Species Act

The intent of the Endangered Species Act of 1973 is to conserve threatened and endangered species and the ecosystems that provide necessary habitat for them. The Act defines **endangered species** as "any species which is in danger of extinction throughout all or a significant portion of its range other than a species of the Class Insecta determined by the Secretary to constitute a pest whose protection under the provisions of this Act would present an overwhelming and overriding risk to man" (16 U.S.C. 1532). A **threatened species** is "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (16 U.S.C. 1532).

- Of the roughly 1,100 species of plants and animals on the Federal list of threatened or endangered species, 105 occur in the Northern United States (appendix B).
- The largest numbers of threatened and endangered species in the Northern United States are found on the Atlantic Coast, Michigan's Upper Peninsula, the Missouri Ozarks, and mountainous West Virginia, followed by the Mississippi River corridor and other river and lake border areas (Flather and others 1999).
- The recovery of Northern United States species such as the bald eagle, peregrine falcon, and small whorled pogonia are due, in large part, to protection afforded under the Endangered Species Act.

Genetic Diversity

Genetic diversity affects the ability of a species to evolve in response to changes in its environment (Soulé 1980). Reduced genetic variation reduces the potential for disease resistance while it increases the likelihood of inbreeding and resulting mutations in individuals (Frankham 1995, O'Brien and Evermann 1988, Ralls and Ballou 1983, Ralls and others 1979, 1988; Wright 1977).

Genes determine the species of an organism; therefore, the diversity of species is a coarse

measure of genetic diversity. Differences in genes among individuals and populations of a species are the next levels of measurement. A **population** is a collection of individuals of a species that potentially interbreed and share a common gene pool. Concern about genetic diversity is most serious for species with populations that are either naturally small or isolated, or populations that have become small because of changes in their environment or impacts from human activity (Nei 1987, Nei and others 1975, Wright 1969).

Managers seek to conserve genetic diversity by managing for viable populations of species across their known range of distribution. It is desirable to preserve genetic diversity through the protection of viable populations in a natural setting, rather than in a laboratory or other site outside a natural habitat. This is especially true of wildlife species, for which the difficulty and costs of conservation can be very high.

- Wildlife species distribution and abundance in Northern U.S. forests have fluctuated since the time of European settlement as result of habitat changes associated first with forest harvest and land clearing practices, and then with reforestation (DeVos 1964, Martin and Klein 1984, Pielou 1991). The distribution and abundance of wildlife species continue to be associated with trends in land cover and use as well as natural successions. Wildlife is also affected by changes in the amount and quality of habitat due to logging, fire, windthrow, insects, and disease (Block and Brennan 1993, Forman 1995, Janetos 1997).
- Examples of wide-ranging forest associated species found across the Northern United States include black bear, white-tailed deer, wild turkey, ruffed grouse, mice and voles, numerous woodpeckers, thrushes, most wood warblers, chickadees, titmice, and raptors.
- Forest carnivores historically and presently found in Northern U.S. forests include large carnivores such as gray and red wolf, coyote, wolverine, lynx, and cougar (Fuller and Kittredge 1996). Other carnivores include red and gray fox, bobcat, and a variety of mustelids (e.g., pine marten, fisher, ermine, long-tailed and least weasels, mink, otter, badger, and striped skunk) (Yamasaki 2003).
- There are at least 150 Neotropical migrant species that breed in forest types common in the Northern United States. Most species breed in more than one forest type. Some Neotropical migratory birds (e.g., wood thrush and cerulean warbler) are declining in some parts of their breeding ranges due to events on their wintering grounds or during migration (DeGraaf and Rappole 1995, Hagan and Johnston 1992, Robbins and others 1992, Terborgh 1989).
- Population trends for waterfowl associated with forested wetlands are complex (Erwin 1996). Wood duck populations have generally increased in the United Sates. The Canada goose, which feeds occasionally in forested wetlands and agricultural fields, has increased in recent years. There have been mid-continental declines in northern pintail, green-winged teal, and Mississippi flyway populations of mallard. The black duck has declined despite stable or increasing forest area in maritime Canada and New England. Blue-winged teal has also declined. Common and hooded mergansers, which feed in wetlands in the northern tier of States, have increased nationally.
- The USDA Forest Service Research Natural Areas Program includes a mandate to

conserve genetic diversity in natural settings. Conservation of genetic diversity is a factor considered by the U.S. Fish and Wildlife Service in the development of conservation and recovery plans for threatened and endangered species.

- Most forestry and wildlife habitat management in the Northern United States depends on wild plants growing in naturally regenerated stands. Silviculturists can prescribe treatments in naturally regenerating stands according to the demands of the locale to favor the most vigorous individuals in order to establish stands with traits that increase their desirability for timber and wildlife.
- Crop and tree breeding programs are forms of genetic resource management that have shown direct benefits by increasing growth and yield. Hybrid species are developed to increase resistance to insects and disease or to increase productivity under specific environmental conditions.
- Seed source testing (provenance testing) often verifies that the seed from local sources grows best over time (Conkle 1973). On the other hand, notable exceptions to this rule suggest more intensive testing might yield nonlocal sources well adapted to variable environmental conditions with other beneficial attributes (Garrett and others 1973, Santamour 1960, Sluder 1963).
- Most land management agencies and private companies have internal policies to maintain genetic variation within commercial forest tree species. These policies guide artificial reforestation, regeneration, and restoration activities.
- In the Northern United States, 15 States have State nursery programs and 21 have State nurseries. There has been general movement away from the production of exotics by public nurseries since the early 1990's (Overton 2001), with the exception of those that grow primarily Christmas tree stock.

Sustainable management attempts to ensure that the trees that remain as breeding stock after a harvest have sufficient genetic variation to maintain the species in the face of environmental change. Continuous **high-grading** (removal of the most vigorous and desirable individuals of a population) is a threat to genetic diversity and may leave breeding stock to produce individuals with undesirable traits.

Criterion 2

Maintenance of Productive Capacity of Forest Ecosystems

Criterion 2. Maintenance of Productive Capacity of Forest Ecosystems

One objective of sustainable forest management is to manage forests to produce wood and nontimber forest products in a way that maintains the ecosystem's capacity for renewal. The capacity of the forest to produce a given product is influenced by the availability of sites suitable for production based on their inherent fertility, accessible water, and forest health. Land-use decisions affect the acreage available for production, and management choices affect short- and long-term yield potential.

Forest products include wood products such as sawlogs, veneer, pulpwood, and fuelwood, and nonwood products extracted from the forest ecosystem such as pinecones, berries, and mushrooms. Forests also provide environmental services and social benefits that are addressed under other criteria.

Land Available for Timber Production

- Ninety-three percent or 159 million acres of forest land in the Northern United States is classified as timberland, land capable of producing timber and not withdrawn from utilization (figure 13). An additional 8.2 million acres of forest land is reserved, withdrawn from timber utilization by statute or administrative action.

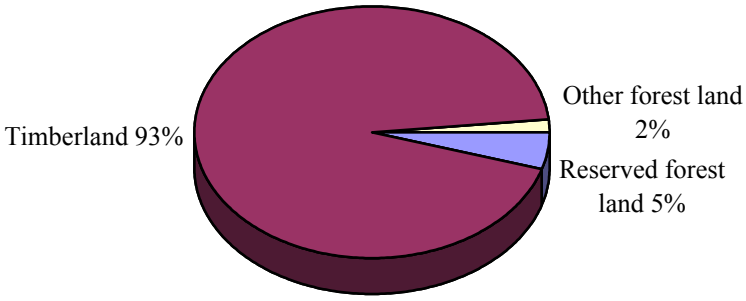


Figure 13. **Forest land use in the Northern United States**. Ninety-three percent of the 169 million acres of forest land in the Northern United States is suitable for timber production (USDA Forest Service 1999a[1]).

[1]Inventory follows methods in Hansen and others 1992.

- Not all land classified as timberland is actually available for harvest. Conditions may be present that limit the viability of harvest, including physical constraints such as steep slope or wetness that affect equipment operability, economic constraints such as poor sale value or costly access road construction, and social constraints such as landowner or local community objectives that preclude timber production.
- The amount of timberland in the Northern United States increased from 1977 to 1997 but appears to have begun to decrease (figure 14). Past increases in forest land were attributed to the conversion of agricultural land. Recent and projected losses of forest land may be due to development trends (USDA NRCS 2001).
- There were an estimated 3.9 million private forest landowners in the Northern United States responsible for 130 million acres of forest land in 1992 (Birch 1996).
- In 1992, the 35 percent of private forest landowners who stated they intended to harvest timber within 10 years owned 61 percent of the private acreage (Birch 1996). The

availability of timberland for harvest can be affected by parcel size and land tenure. Landowners with large parcels or long tenure are more likely to harvest their timber.

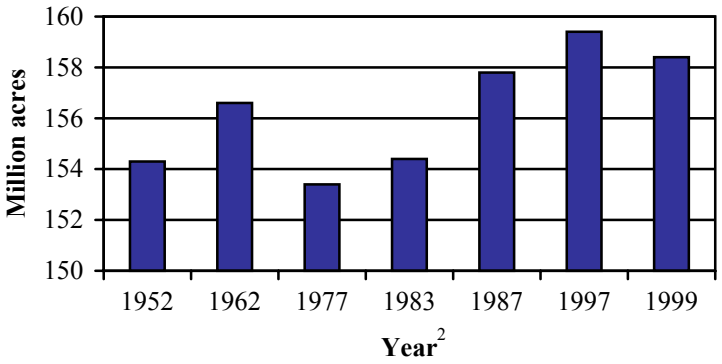


Figure 14. **Trends in timberland area in the Northern United States, 1952–1999**. Timberland area increased from 1977 to 1997, but has begun to decrease (Smith and others 2001, USDA Forest Service 1999a[1]).

[1]Inventory follows methods in Hansen and others 1992.

[2]Data collected for individual States on varying cycles. Data summarized as shown.

- Most small woodlot owners do not want to see the majority of their woods harvested at one time; therefore, landowners with less than 20 acres of timberland are more likely to use silvicultural systems such as single-tree selection or group selection than clearcuts or shelterwood cuts. In the New England and Mid-Atlantic States, 75 percent of all private landowners own less than 20 acres of timberland, compared with 67 percent in the Central States and 53 percent in the Lake States (Birch 1996).
- About 19 percent of the timberland in the Northern United States is on sites with excellent potential productivity, 34 percent is found on good sites, and the remaining 47 percent is on sites with average to low productivity (Hansen and others 1992).
- Extensive areas of timberland in the Northern United States are understocked or past an optimal age from economic or silvicultural perspectives. On many of the most productive sites, stocking levels can be enhanced to produce more wood and thereby lessen the harvesting pressure on sites with lower potential productivity and on physically or biologically sensitive sites.
- The Northern United States has relied more on natural regeneration than plantations to maintain and expand its areas of timberland. In 1992, there were only 3.5 million acres of timberland plantations in the Northern United States, the majority of which are located in the North Central States (Hansen and others 1992). This number had increased to 4.3 million acres by 1997 (Smith and others 2001).

Growing Stock Volume

- Growing stock volume on timberland more than doubled from 1952 to 1999, increasing from 104 billion cubic feet to 215 billion cubic feet (table 6, Smith and others 2001, USDA Forest Service 1999a). Net annual growth increased by 45 percent and removals by 54 percent during that time period, yielding a growth-to-removals ratio of 1.8:1. By 2040, total growing stock is projected to increase by 23 percent over 1999. Net annual growth is expected to decrease by 9 percent and removals to increase by 40 percent, yielding a growth-to-removals ratio of 1.2:1.
- This projected downward trend in the growth-to-removals ratio represents a substantial

Table 6. **Changes in inventory, growth, and removals on timberland in the Northern United States** (in million cubic feet) (Haynes 1990, Smith and others 2001, USDA Forest Service 1999a[1]).

	1952	1977	1987	1997	1999	2040 (projected)
Softwoods						
Inventory	27,053	43,850	47,618	49,376	49,568	62,033
Net annual growth	973	1,558	1,288	1,169	1,179	1,260
Removals	622	692	726	668	782	1,096
Growth-to-removals ratio[2]	1.6	2.3	1.8	1.8	1.5	1.1
Annual mortality	216	324	368	456	457	—
Hardwoods						
Inventory	76,695	119,158	142,420	164,874	165,202	202,343
Net annual growth	2,743	3,790	4,224	4,251	4,203	3,643
Removals	1,279	1,803	1,983	2,104	2,146	3,000
Growth-to-removals ratio[2]	2.1	2.1	2.1	2.0	2.0	1.2
Annual mortality	475	824	875	1,172	1,194	—
Total						
Inventory	103,748	163,008	190,038	214,251	214,771	264,376
Net annual growth	3,716	5,349	5,512	5,420	5,382	4,903
Removals	1,901	2,495	2,708	2,772	2,929	4,096
Growth-to-removals ratio[2]	2.0	2.1	2.0	2.0	1.8	1.2
Annual mortality	690	1,149	1,243	1,628	1,651	—

[1]Inventory follows methods in Hansen and others 1992.
[2]Represents a simple ratio; unit is not million cubic feet.

change in both the growth rate of trees and the intensity of management activities. The second- and third-growth forests of the Northern United States are reaching maturity. With this advance in age, growth rates have slowed while harvesting has increased.

- Net growth exceeds removals for hardwoods and softwoods in all Northern U.S. provinces except Province M212, where softwood removals exceed net growth (table 7).
- Hardwoods account for 77 percent of total growing stock volume and represent the majority of volume in all Northern U.S. provinces (figure 15). The Laurentian Mixed Forest Province 212 has 36 percent of the total growing stock volume and the largest shares of hardwood and softwood volume.

Table 7. **Growth-to-removals ratios by province in the Northern United States** (USDA Forest Service 1999a[1]).

Province	Softwoods	Hardwoods	Total
212	1.8	2	1.9
M212	0.7	2	1.3
221	1.8	2.2	2.1
M221	2.7	2.4	2.5
222N	2.2	1.3	1.4
222S	4.9	2.4	2.5
231	ns	ns	ns
232	1.3	1.2	1.2
234	ns	ns	2.3
251	4.7	2.5	2.5

[1]Inventory follows methods in Hansen and others 1992.
ns = not sufficient data for calculation

Nontimber Forest Products

- The economic importance and potential

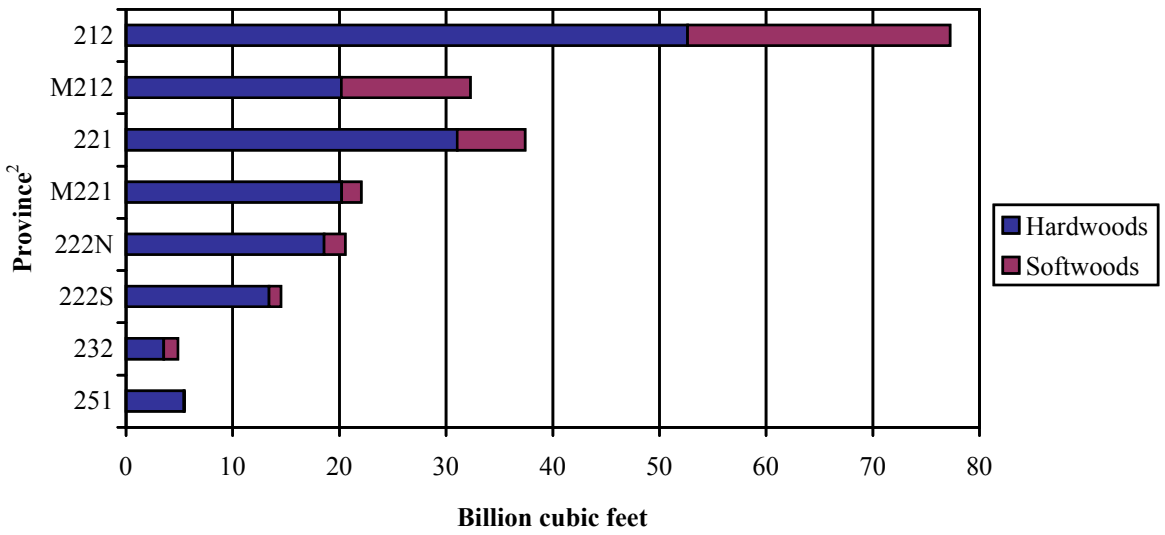


Figure 15. **Distribution of growing stock volumes on timberland in the Northern United States by province** (USDA Forest Service 1999a[1]).

[1]Inventory follows methods in Hansen and others 1992.

[2]Provinces 231 and 234 have been omitted because the amounts are too small to be evident on the graph.

impacts of nontimber harvest activities are not well known. The majority of nontimber products are not regulated and there is no systematic effort to collect data. Some trends can be gleaned, however, in areas where permits are issued and local studies have been conducted. For example, one study found that 138 different special forest products were collected in and around the Hiawatha National Forest in Michigan (Emery 1997).

- Ginseng has recently become scarce on national forests in the Northern United States and is now listed as threatened in many States (Padley 1997). Ginseng has been regulated in Wisconsin since 1975, where it is now cultivated to meet demand. It takes at least 100 ginseng roots to make a pound.
- Plant theft from national forests is a significant problem. For example, showy orchids have nearly vanished from national forests in the Central States since the 1960's (Padley 1997).

Criterion 3

Maintenance of Forest Ecosystem Health and Vitality

Criterion 3. Maintenance of Forest Ecosystem Health and Vitality

Forest health is difficult to assess at any one point in time, since forests are dynamic and influenced by many factors. Measures of forest health include forest age and composition, trends in tree growth and mortality, tree crown condition, vulnerability to forest health stressors and their frequency of occurrence, and the condition of soil, water, and wildlife. Forest condition throughout the Northern United States is assessed annually through the USDA Forest Service's Forest Health Monitoring Program.

It is important to maintain healthy forests that are resilient to forest stressors in both urban and rural landscapes. Combinations of stressors, such as insects and pathogens combined with drought, cause the greatest impact. The impact from various stressors can result in decline in a forest stand as trees within the stand die back and deteriorate. This decline may eventually affect forest composition and productivity. All of these factors influence the selection of appropriate management strategies.

- The last century has brought an influx of human-influenced factors to Northern U.S. forests, including exotic insects and pathogens, invasive plants, and air pollution. These factors, especially when they occur in combination, have the potential for creating a greater impact on the health of urban and rural forests than natural factors alone.

Insects and Disease

- Population levels of native insect pests vary each year; fluctuations are influenced by weather conditions, availability of food sources, and occurrence of insect pathogens and predators (figure 16).

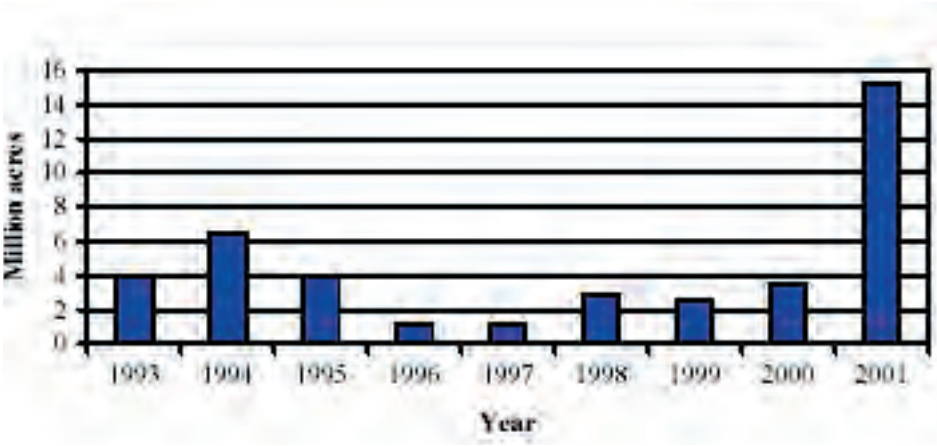


Figure 16. **Acres of defoliation**. Between 1993 and 2001, over 40 million acres were defoliated by native insects in the Northern United States. The large increase in 2001 was due primarily to a forest tent caterpillar outbreak in the Lake States (Source: USDA Forest Service).

- Historically, conifers in the Northern United States have been impacted by spruce budworm, jack pine budworm, and pine false webworm. Hemlock looper has caused significant dieback and mortality to eastern hemlock. The main native defoliators of oaks are oak leaftier and oak skeletonizer. Maples are affected by the maple leaf cutter and other defoliators. Forest tent caterpillar has also caused extensive defoliation of hardwoods

(USDA Forest Service 2001).

- Since the turn of the century, exotic or introduced forest pests have had dramatic impacts upon Northern U.S. forests. These introduced pests usually have no natural factors in their new environment that can control their population. Of known exotics, 15 insects and 7 pathogens have had widespread impacts; many have become serious, persistent forest pests (table 8). Some, such as chestnut blight, Dutch elm disease, butternut canker, beech bark disease, white pine blister rust, and gypsy moth, have had long-term, devastating effects beyond the range of expected variation.

- Recently introduced pests are also becoming significant concerns. Examples include the hemlock woolly adelgid, pine shoot beetle, Asian longhorned beetle, and emerald ash borer. Such introductions have prompted quarantines and efforts towards eradication. The USDA Animal Plant Health Inspection Service is responsible for detecting and mitigating the initial introduction of exotic pests.

Table 8. **Introduced insects and pathogens in the Northern United States.** Several insects and pathogens have been introduced into the United States from Europe and Asia since the early 1800's, causing significant tree damage and mortality (USDA Forest Service 2002a).

	Origin	Year of entry
Insects		
Elm leaf beetle	Europe	1834
Gypsy moth	Europe	1869
Larch sawfly	Europe	1880
Larch casebearer	Europe	1886
Beech scale	Europe	1890
Pear thrips	Europe	1904
Balsam wooly adelgid	Europe	1908
Elm bark beetle	Europe	1909
Introduced pine sawfly	Europe	1914
Birch leafminer	Europe	1909
Hemlock woolly adelgid	Europe	Prior to 1953
Pine shoot beetle	Europe	Prior to 1992
Asian gypsy moth	Asia	1992
Asian longhorned beetle	Asia	Prior to 1997
Emerald ash borer	Asia	Prior to 2002
Pathogens		
Chestnut blight	Asia	1904
White pine blister rust	Europe	1906
Larch canker	Europe	1927
Dutch elm disease	Europe	1930
Butternut canker	Asia (uncertain)	Prior to 1960
Scleroderris canker	Europe	1962
Dogwood anthracnose	Asia (uncertain)	Prior to 1976

Abiotic Stressors

- Abiotic factors such as drought, ice storms, wind, and fire have historically caused significant damage in the Northern United States. Drought conditions that occurred during the 1980's and 1990's, in combination with other factors, caused a decline in tree health in some areas. The largest ice storm in recent years occurred in January 1998, impacting approximately 17 million acres of rural and urban forests in Maine, New Hampshire, Vermont, and New York. Wind damage has been significant in northern Minnesota and New York. Fires consume an average of 225,000 acres in the Northern United States each year.

- Exposure to atmospheric ozone and acidic deposition are significant threats to the forest

ecosystem. Ozone-induced foliar injury has been detected on many of the sensitive plants surveyed at biomonitoring sites in the Northern United States (figure 17).

- Studies show that acidic deposition has contributed to a regional decline in available calcium in spruce-fir forests in New York and New England. There is also evidence that acidic deposition has reduced cold tolerance of high-elevation red spruce, resulting in frequent winter injury of foliage.

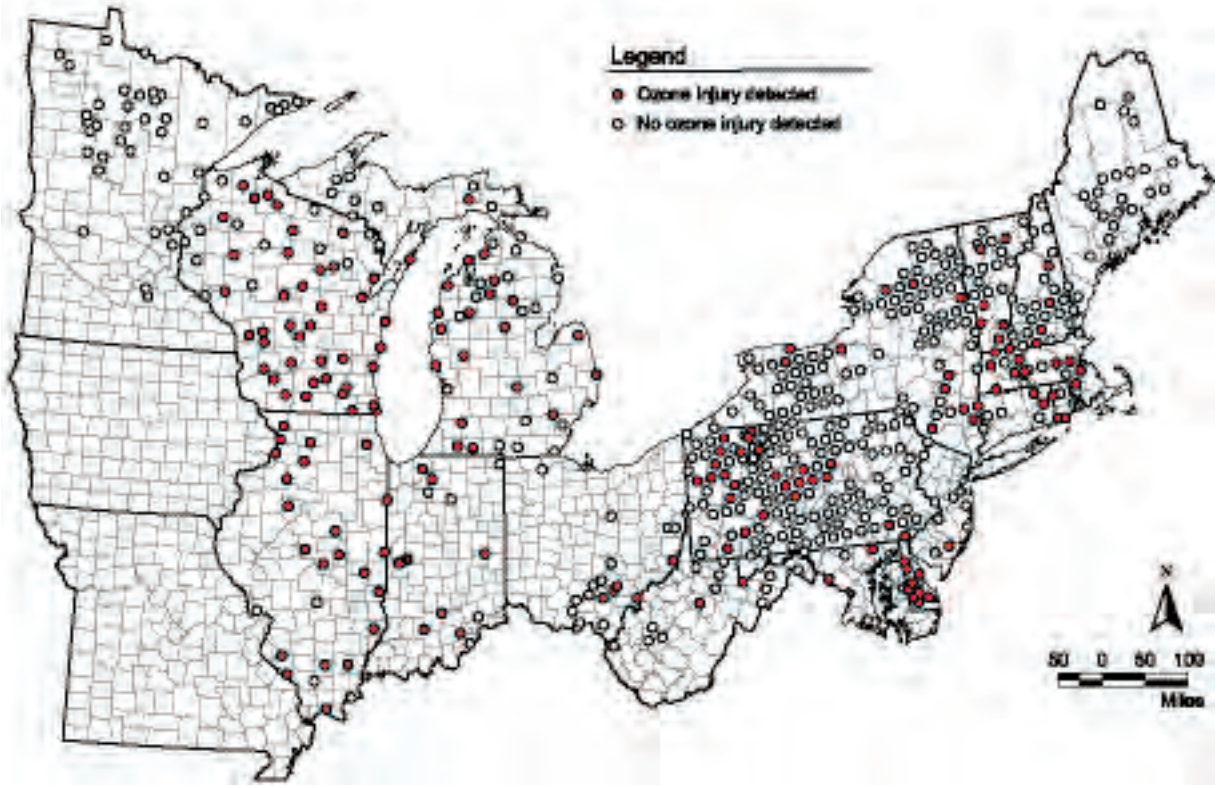


Figure 17. **Ozone injury detected, 1999**. Ozone injury was detected on biomonitoring sites associated with Forest Health Monitoring plots across the Northern United States (Source: USDA Forest Service).

- Several factors have been associated with the decline of sugar maple in New England, New York, and Pennsylvania. In response to concerns about the status of the maple resource, the United States and Canada formed the joint North American Maple Project in 1987. Selected sugarbush and forest maple stands in the Northern United States and Eastern Canada are monitored on an annual basis.

Noxious Weeds

- Of the thousands of plant species introduced into the United States, 94 taxa are officially recognized as Federal noxious weeds. Invasive plants are currently estimated to occupy well over 100 million acres, and populations are predicted to increase by 8–20 percent annually. When invasive plants, such as mile-a-minute weed and Japanese knotweed, colonize a clearcut area, they become competitive with forest seedling regeneration. They can also displace native plant species, which can impact wildlife habitat.

Deer Browsing

- The increasing white-tailed deer population in the eastern United States affects forest sustainability and has impacted plant species composition and community structure (Stromayer and Warren 1997). Deer browsing has a profound impact on the establishment of regeneration, the density of hardwood seedlings, and the presence of understory plants (ferns, flowers, and shrubs). These factors ultimately influence biodiversity and affect other wildlife.

Criterion 4

Conservation and Maintenance of Soil and Water Resources

Criterion 4. Conservation and Maintenance of Soil and Water Resources

Soil Conservation

The emphasis in soil conservation is on maintaining site productivity and soil resource functions. Soil provides a reservoir of water for plants and streams between rainstorms, and is a storehouse of nutrients for plants and animals. It serves as an anchor for vegetation and is the seasonal or permanent home to a variety of burrowing animals, insects, and microscopic organisms. The organically enriched and biologically active portions of the soil reduce excess nutrients and transform pollutants, thus contributing to a healthy environment.

- **Soil erosion** occurs when the rate of soil loss from a site is greater than the rate of soil formation. Soil erosion from land clearing has had a significant impact in the Northern United States (Shands and Healy 1977).
- Timber harvest activities, road building, and lack of maintenance on roads and recreation trails are the most common contemporary sources of erosion in the Northern United States. Prescribed burns that create excessive ground temperatures and expose the root layer can also increase the potential for erosion. Management practices are widely available to minimize erosion from these activities.
- In the Northern United States, effects on soil organic matter content and nutrient stores are related to timber harvesting, land use history (i.e., fire, agriculture), acid deposition (acid precipitation and dry deposition), and soil erosion.
- Widespread reductions in productivity due to the cumulative effects of soil erosion, harvest, and acid deposition on nutrient cycles are not clearly demonstrated by empirical evidence to date (Hallett and Hornbeck 1997, Horsley and others 2000, Nuengsigkapian 1998). Localized effects on productivity are anticipated in the long term. For example, forest productivity may remain relatively unaffected on sites with large nutrient stores in the soil, while it may decrease on soils with inherently low nutrient stores.

Water Resources in the Northern United States

- Roughly 15 million acres in the Northern United States are water bodies and streams in permanent open water area (USDA NRCS 2001). There are approximately 960,000 acres of lakes and nearly 13,400 miles of fishable streams on national forests alone. Major river systems include the Mississippi, Hudson, Ohio, Illinois, Susquehanna, Delaware, Connecticut, and Missouri. The Great Lakes—Superior, Michigan, Huron, Erie, and Ontario—form much of the northern border of Northern United States. The Eastern States are bordered by Atlantic coastal bays and estuaries. Notable features include Chesapeake Bay, Delaware Bay, Long Island Sound, Massachusetts Bay, Casco Bay, and Penobscot Bay.
- In addition to surface waters, the region has extensive ground water resources. Bedrock aquifers are prevalent at varying depths throughout the Northern United States. Ancient sand lenses are a source of ground water in the Midwest and coastal plains. Aquifers in glacial deposits are common in the northern portions of the region.

Water Resource Quality

The challenge in protecting water resource quality in the Northern United States lies in targeting the actual causes of water quality degradation. Impacts on water resource quality may be the result of activities or natural disturbances that affect the land and vegetation of a watershed or aquifer recharge area. They may also be the result of activities, like point source pollution or over-fishing, that directly impact the physical or chemical nature of the water resource or the biota.

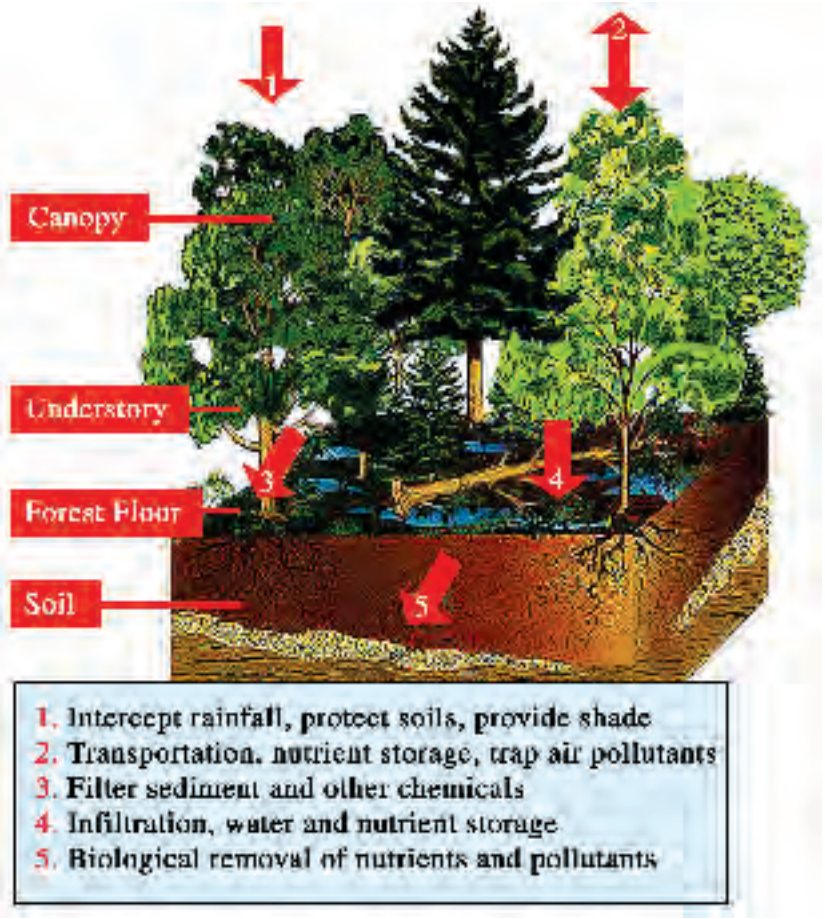


Figure 18. **Forest functions**. Physical, chemical, and biological processes in forests are key to sustaining water quality and supply, and watershed health.

Water resource quality is often assessed on a watershed basis. Most watersheds encompass a mosaic of land uses, including forests. Many forests in the Northern United States are intermingled with farmland, pasture, and, increasingly, suburban development. Watersheds with a large proportion of forest land are generally associated with good water quality (Omernik and others 1981). Forests help sustain watershed functions (figure 18). Forty-one percent of the Northern United States is in forest cover (USDA Forest Service 1999a).

- Preliminary data assembled by the U.S. Environmental Protection Agency indicate that surface waters supply nearly 4,000 water systems in the Northern United States, serving over 76 million people (table 9). Protection of surface and subsurface water quality for drinking water is an important benefit of forested watersheds.
- Sediment problems in many forest streams in the Northern United States do not reflect a response to current land use but are the result of erosion from land clearing and the use of rivers to transport logs a century or more ago (figure 19, Bassett 1987).
- Forest management operations have comparatively less impact on water quality than agriculture, urban development, and most other human land uses. A report by the Council

Table 9. **Surface water supply sources.** Forest land in the Northern United States helps protect surface water supplies for over 76 million people[1] (Source: U.S. Environmental Protection Agency).

Forest land ownership	Number of watersheds	Number of water systems	Population served
State and private	512	3,074	68,746,700
National Forests	86	925	7,750,000
Total	**598**	**3,999**	**76,496,700**

[1]Data include Virginia.

on Environmental Quality indicated that forest land accounted for only 5.2 percent of nonpoint source contributions of total suspended sediment nationwide in 1980 (figure 20).

Poorly planned forestry activities have the potential to degrade water resources, but impacts such as sedimentation from forest operations and increased water temperatures due to canopy removal can be eliminated or minimized with proper care.

- Agricultural runoff is a significant source of nonpoint source pollution that can be reduced by using streamside forests as buffers. Agricultural runoff includes herbicides, fungicides, insecticides, nitrate and phosphate components of fertilizer, and animal waste from agricultural land and operations. Ninety-five percent of the watersheds in the Northern United States show moderate to high levels of agricultural runoff.
- Since over three-quarters of the surface water supply systems in the Northern United States have the potential to be affected by State and private forest land stewardship, public and private forest landowners share the responsibility to protect drinking water. This is leading to some vital public-private partnerships.

Figure 19. Logging in New Hampshire's White Mountains in the early 1900's typifies the extensive harvesting that occurred across the Northern United States (USDA Forest Service photo).

- Over 350 private land trusts in the Northern United States have identified watershed and water quality protection as an objective of their efforts (Land Trust Alliance 1998). The USDA Forest Service's Forest Legacy Program enables States to purchase properties or conservation easements where forest lands provide high watershed values and are threatened by conversion to other land uses.

The New York City Department of Environmental Protection is implementing an aggressive effort to purchase forest lands and conservation easements in key areas to safeguard the drinking water supply to 9 million residents in the metropolitan area. It is working with the USDA Forest Service, State forestry agencies, other Federal, State, and county agencies, and private organizations to promote voluntary programs to protect water quality without compromising the economic viability of farming and forestry in the watersheds. The cost of this protection strategy is far less than the nearly $7 billion needed to construct filtration plants (National Research Council 2000).

Riparian Areas

Riparian ecosystems include soil, surface structure (woody debris, rocks, depressions), and plant and animal communities along lakes, streams, and wetlands. Because of their position in the landscape, riparian ecosystems interact with the flow of surface and ground water from upland areas and play an important role in filtering runoff, reducing excess nutrients, and transforming pollutants. They also provide food and cover for aquatic and terrestrial species. Species abundance and richness tend to be greater in riparian ecosystems than in adjacent uplands (Odum 1979).

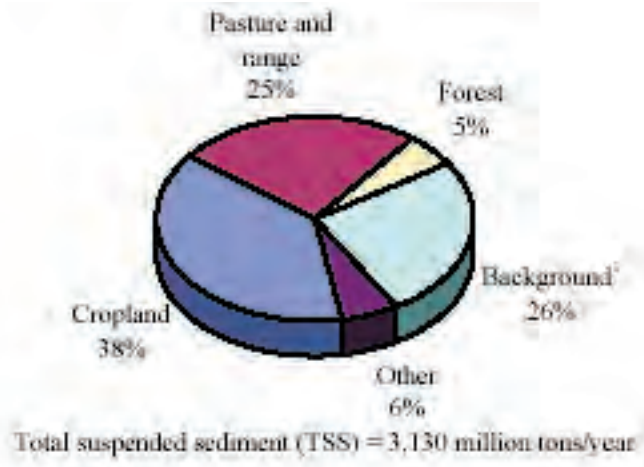


Figure 20. **Sources of suspended sediment.** Nationally, forest land contributed about 5 percent of the total suspended sediment from nonpoint sources in 1980 (Welsch 1991).

[1]Naturally occurring sediment in undisturbed landscapes.

- In the past, streamside forests in the Northern United States lined most rivers and streams, but deforestation associated with agricultural and urban expansion has drastically reduced their extent. In agricultural areas, many floodplain forests have been reduced to isolated fragments no longer capable of supplying rivers with essential woody debris or an adequate organic food supply for healthy fisheries.
- The loss of trees along streams in the Northern United States has resulted in increases in water temperature and decreases in in-stream woody debris critical to the successful maintenance of cold-water fish such as trout. The linkage between streamside forests and the health of fish stocks may stretch to ocean fisheries as well, where the natural process of delivering large quantities of wood from the watershed to the sea has essentially been severed (Maser and Sedell 1994).
- The presence or absence of trees adjacent to a stream channel may be the single most important factor affecting stream insects, an essential part of the food chain in aquatic systems. In the Northern United States, almost half of the watersheds have more than 56 percent of their stream miles in forested cover, while nearly a fifth have more than 89 percent (Jones and others 1997).

Restoring streamside and lakeside forests can help remove pollutants in runoff or reduce their effects, and can increase the biological diversity and productivity of aquatic communities by improving habitat and adding to the organic food base.

- The Federal Wild and Scenic Rivers and the American Heritage Rivers Programs offer opportunities to protect streamside forests and riparian functions. The Northern United States is home to 39 Wild and Scenic River segments covering 1,803 miles, and 9 nationally designated American Heritage Rivers (USDI National Park Service 2001, U.S. Environmental Protection Agency 2002).

Stream Hydrology

Forested watersheds are important for storing water, providing for its long-term release, and recharging ground water. They are the source of approximately 66 percent of the total national water yield. Land use and cover ultimately affect the hydrology of streams, lakes, and wetlands in a watershed. Forest land tends to have a moderating influence on peak flows compared to agricultural or developed land. Pavement and other impervious surfaces in developed areas cause rainfall to run off into streams and other water bodies more rapidly than under natural conditions (figure 21). In forested systems, rainfall is stored in surface depressions and infiltrates into the ground.

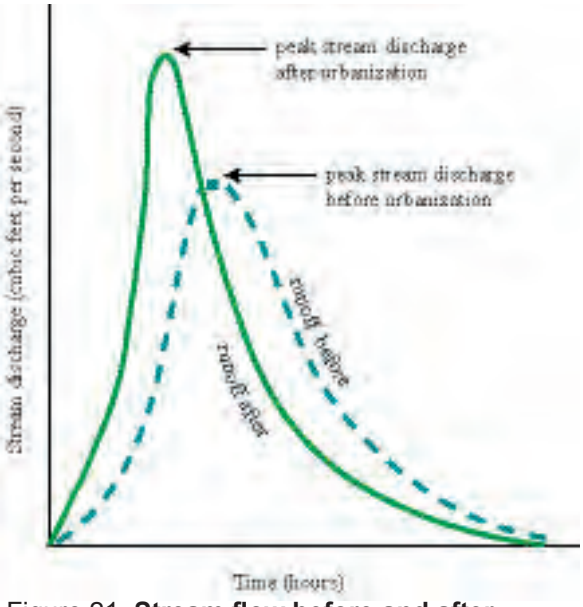


Figure 21. **Stream flow before and after urbanization.** Runoff enters a stream faster following urbanization, leading to higher peak stream discharge than in a natural system (Source: adapted from Federal Interagency Stream Restoration Working Group 1998).

- The natural hydrology and biological integrity of streams begins to degrade when just 10 percent of the watershed is covered by impervious surfaces (figure 22). Increases in surfaces such as roads, sidewalks, roofs, and compacted soils can increase runoff volume and rate, and decrease a stream's capacity to handle floods.

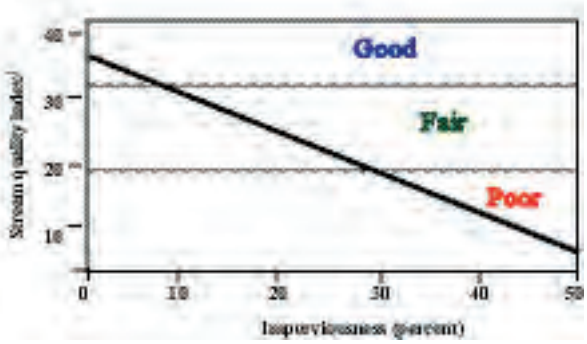


Figure 22. **Effects of imperviousness on stream quality index.** Streams show signs of degradation of natural hydrology and biotic integrity when watershed imperviousness reaches 10 percent (Schueler and Galli 1992).

[1]Values are based on a ratio of selected stream invertebrates reflecting different levels of water quality.

Wetlands

Wetlands provide a multitude of ecological, economic, and social benefits. They provide habitat for fish, wildlife, and a variety of plants.

They serve as nurseries for many saltwater and freshwater fish and shellfish of commercial and recreational importance. Wetlands are an important landscape feature because they hold and slowly release floodwater and snow melt, recharge ground water, act as filters to cleanse water of impurities, recycle nutrients, and provide wildlife viewing and recreation opportunities for millions of people. Conversely, because of their position in the landscape, pollution, drainage, urban development, and other activities that may not necessarily occur in wetlands can impair wetland functions.

- The Northern United States had an estimated 41 million acres of wetlands on non-Federal land and water areas in 1997, roughly half of that present in the late 1700's (Dahl 1990, USDA NRCS 2001). Forested wetlands comprise the largest segment of wetlands in the Northern United States (figure 23).
- Gross losses of palustrine (including forested) and estuarine wetland types in the Northern United States between 1992 and 1997 totaled 131,800 acres. Losses were reported for changes in land use to agriculture (33 percent), silviculture (18 percent), development (46 percent), and other (3 percent) (USDA NRCS 2001). Most silvicultural treatments of forested wetland types in the Northern United States do not result in long-term changes in a site's underlying hydrology. In these situations forests will usually regenerate after harvest and the wetlands character is retained.

Aquatic Biodiversity

The historical emphasis in water resource conservation has been to maintain the chemical characteristics in surface and ground water in order to meet specific human demands such as water for drinking, industrial cooling, irrigation, and recreational activities such as swimming. More recently, emphasis has been placed on the need to maintain the physical, chemical, and biological integrity of the Nation's waters. This emphasis includes maintaining both the resilience of aquatic ecosystems in the face of disturbance or stress and the stability of streambeds and streambanks.

- Of 642 watersheds across the Northern United States, a quarter of them had 5 or more known species at risk, almost half had between 2 and 5 species at risk, and a fifth had at least 1 species at risk. The status of 10 percent of the watersheds is currently unknown (U.S. Environmental Protection Agency 1997).
- Aquatic biodiversity is affected by factors such as pollution, the introduction of exotic and invasive species, changes in water temperature, bank erosion, sedimentation, and loss of woody debris or natural carbon and nutrient inputs from streamside vegetation.
- Exotic species can harm aquatic resources and their use. Exotic plants that threaten aquatic habitats include European frog-bit, hydrilla, fragmites, flowering rush, purple loosestrife, and water chestnut. Eurasian watermilfoil reduces populations of invertebrates and fish such as bluegill and largemouth bass. Exotic fish include popular species such as bass, brown trout, and rainbow trout, as well as carp, round goby, rudd, Eurasian ruffe, white perch, and sea lamprey. Hybridization of introduced fish species with native species has reduced genetic diversity. Exotic crustaceans include the rusty crayfish and the zebra mussel. Mute swans destroy wetland habitat and displace native wetland bird species.

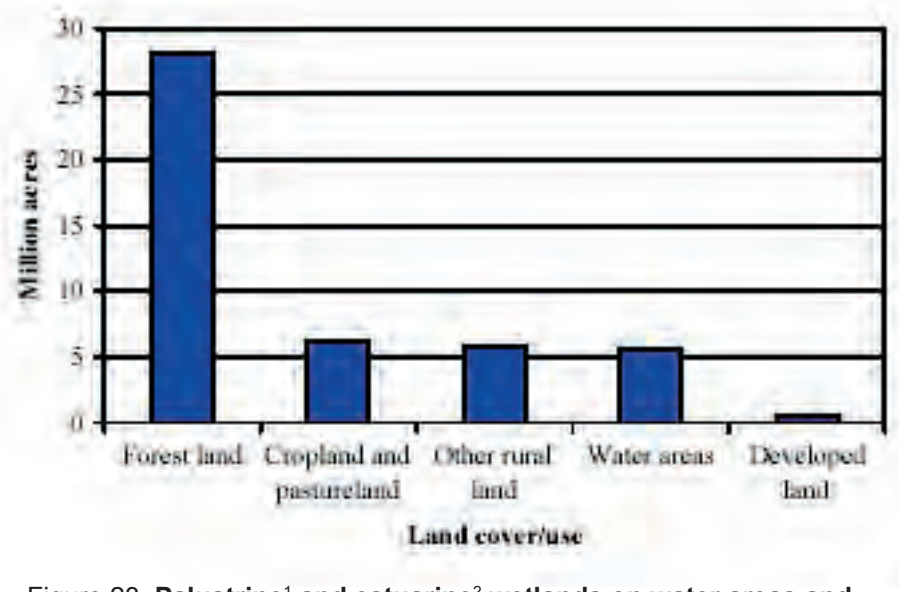


Figure 23. **Palustrine[1] and estuarine[2] wetlands on water areas and non-Federal land by land cover/use in the Northern United States, 1997**. Forested wetlands comprise the largest percentage of wetlands in the Northern United States (USDA NRCS 2001).

[1]Palustrine wetlands include all nontidal wetlands dominated by trees, shrubs, persistent emergent plants, or emergent mosses or lichens, as well as small, shallow open water ponds or potholes. They are often called swamps, marshes, potholes, bogs, or fens (Cowardin and others 1979).

[2]Estuarine wetlands are tidal wetlands that are usually semi-enclosed land but have open, partly obstructed or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land (Cowardin and others 1979).

Sustainable forest management can contribute to healthy aquatic ecosystems. Management actions include managing riparian vegetation adjacent to lakes and streams to ensure a continual source of large wood debris, restoring streamside forest diversity and health, managing riparian vegetation to discourage beaver habitation along important cold-water streams, managing roads to minimize sedimentation, reducing sediment input through stabilization and sediment traps, managing recreation pressure on aquatic systems, and restoring habitat.

Criterion 5

Maintenance of Forest Contribution to Global Carbon Cycles

Criterion 5. Maintenance of Forest Contribution to Global Carbon Cycles

Carbon is a global concern because increasing carbon-containing gases in the atmosphere may lead to climate change. Tracking carbon in forests helps scientists study the global carbon cycle and will verify the results of adopted mitigation measures. The carbon stored in forests and forest products mitigate the amount of carbon released into the atmosphere, which may help delay global climate change.

Inventory of Carbon in Forest Ecosystems

Growing forests naturally store carbon. Forest ecosystems store carbon in vegetation, the forest floor, and soil. The carbon cycle in forest ecosystems includes carbon fixation through photosynthesis and carbon emissions through respiration, the decay of organic matter, and combustion due to fire. The age and vigor of forest vegetation affects the rate of carbon sequestration in a forest ecosystem and the overall inventory of stored carbon. Trees represent the most dynamic component of this carbon pool (figure 24).

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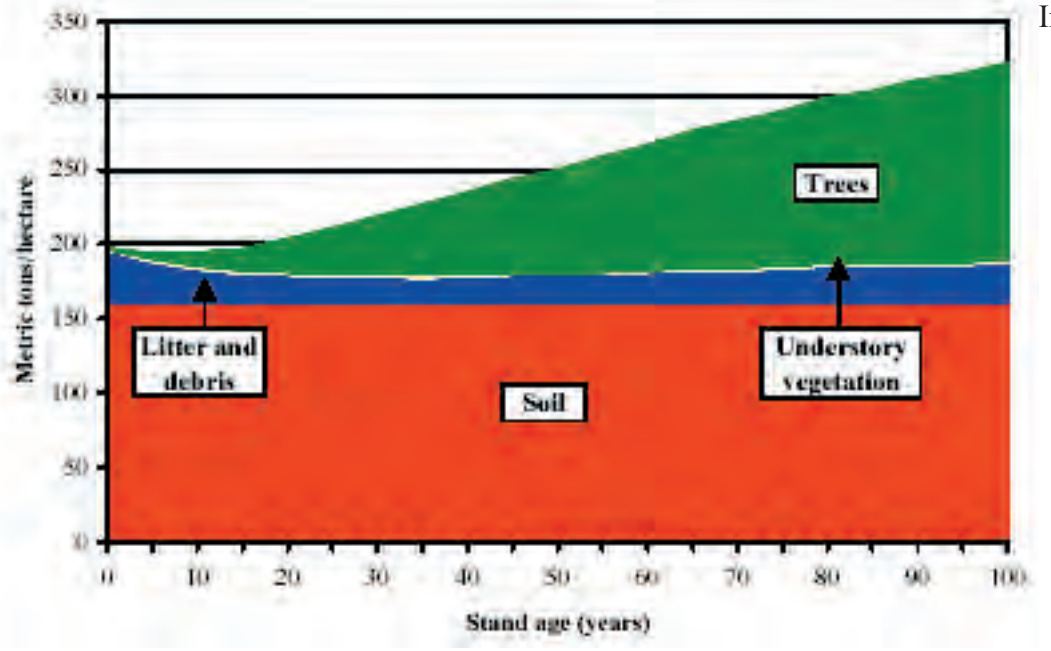

Figure 24. **Estimated forest carbon stores in a maple-beech-birch forest type in the Northern United States** (on fully stocked timberland under average management after final clearcut harvest) (Data from Birdsey 1996).

Northern U.S. forests, biomass of standing large trees is 2,920 million tons, biomass in stumps and roots is 1,166 million tons, and biomass in saplings is 1,074 million tons (McWilliams and others 2000). Trees are generally about 50 percent carbon. Overall, only about 41 percent of the standing tree biomass in the Northern United States is in the main stem of merchantable live trees (trees greater than 12.5 cm diameter at breast height) (figure 25).

- Eighty percent of the standing tree biomass in the Northern United States is comprised of hardwood species.

- The largest proportion of the total carbon inventory in Northern U.S. forests is found in the soil. In 1992, the soil carbon and litter layer component of Northern U.S. forests was approximately 63 percent of the total forest carbon pool.

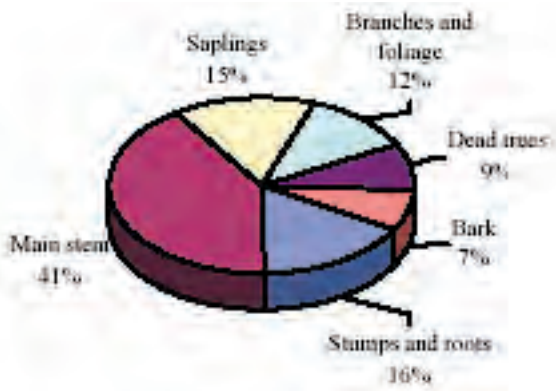

Figure 25. **Estimated distribution of biomass for trees in Northern U.S. forests, 1997** (McWilliams and others 2000).

Changes in Forest Carbon Inventory

Changes in forest carbon inventory in the Northern United States are affected by the rates of forest growth, harvest activity, loss of forest land due to conversion to other land uses, and loss of forest cover due to fire or other natural disturbances. In the absence of harvesting or other disturbance, carbon inventories in forests change relatively slowly and are difficult to measure over a short period of time.

- The carbon inventory in Northern U.S. forests is higher than in forests of any other region of the United States (figure 26). The carbon inventory was 13.4 billion metric tons in 1992 and is projected to increase to 17.6 billion metric tons by 2040. An underlying factor is that Northern U.S. forests are not harvested as heavily compared to growth as forests in the South and West.

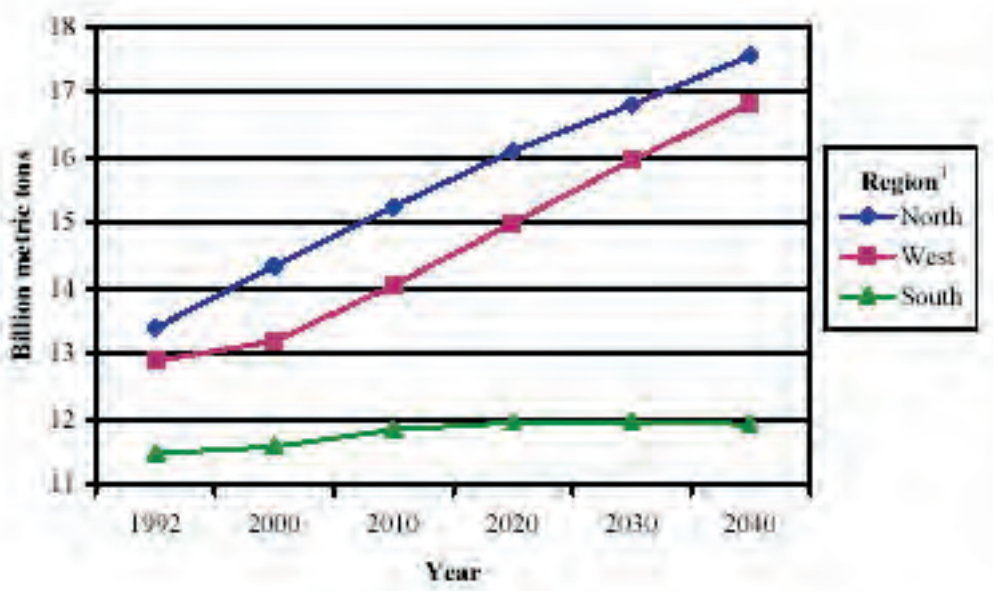

Figure 26. **Forest carbon inventory projections by regions of the conterminous United States** (Birdsey and Heath 1995).

[1]North–Connecticut, Delaware, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia, and Wisconsin

West–Alaska, Arizona, California, Colorado, Hawaii, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming

South–Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia

Carbon in Wood Products

Carbon from forests can remain stored in wood products long after forests are harvested.

- While forest harvesting will decrease the carbon inventory on the harvested site, the overall effect on the total amount of stored carbon will depend on the ultimate use of the harvested wood.
- Harvested carbon can be tracked in four general categories: wood products, landfills, wood burned for energy as a substitute for fossil fuel, and carbon emitted from wood that is not used as an energy source (figure 27).

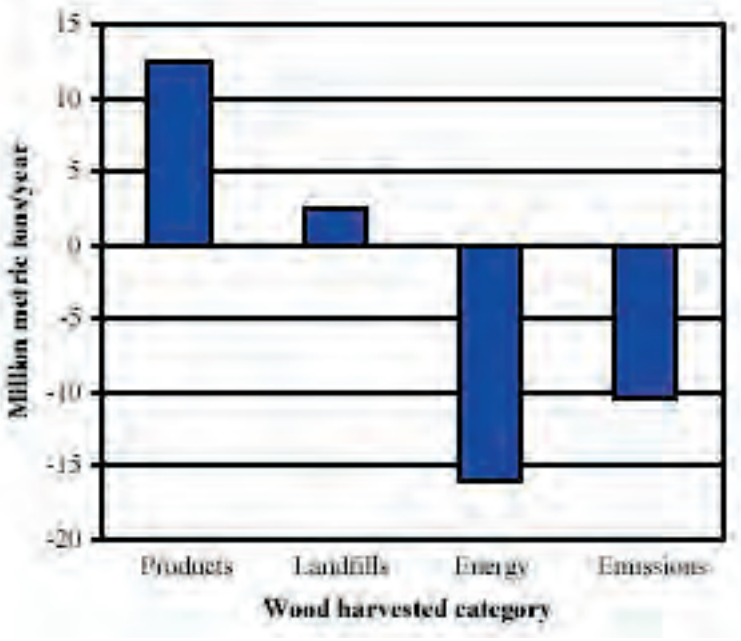

Figure 27. **Estimated average annual carbon change in harvested wood from Northern forests by category, 1980-1990.** Negative carbon change indicates release of carbon into the atmosphere (Heath and others 1996).

- The temporal dynamics of carbon stored in managed compared with unmanaged forest stands makes it difficult to provide advice for maximizing carbon storage for the Northern United States as a whole.

Criterion 6

Maintenance and Enhancement of Long-term Multiple Socio-economic Benefits to Meet the Needs of Societies

Criterion 6. Maintenance and Enhancement of Long-term Multiple Socio-economic Benefits to Meet the Needs of Societies

Forests are valued for the economic, cultural, social, and spiritual benefits they provide. Tracking the diverse values of forests as well as shifts in the demand for forest products and services can provide insights for the future, such as potential drains on the forest resource and opportunities for management.

Production of wood and nonwood products is dependent upon the available supply of raw materials, the demand for finished products, and the capability to process raw materials into desired products. While market forces are a major factor influencing demand for resource-based goods and services, nonmarket forces—such as the desire to sustain biological diversity or to dwell in or visit a natural place—remain critical factors. Shifts in demand can serve as an alert to potential drains on forest resources; however, the sustainability of forests lies primarily in the conservation and management of the resources.

- The Northern United States has a finite land base of 413 million acres. Though forested area has been increasing over the last century, it is leveling off and is currently at 169 million acres. Given a population of 121 million people in 2000, there are 3.4 acres of land, which includes 1.4 acres of forest land, per resident from which goods and services can be derived. Most forests can provide multiple goods and services simultaneously; however, there will always be situations in which multiple activities and desired uses are incompatible.

Wood Volume Removals

- Wood volume removals from timberland growing stock and other sources in the Northern United States totaled nearly 5.1 billion cubic feet in 1996—78 percent of which consisted of hardwoods. About 69 percent of the total output was harvested for roundwood products, 27 percent was left at logging sites, and the remaining 4 percent was removed for cultural reasons or obtained from land converted to nonforest uses (figure 28). **Roundwood** refers to wood suitable for primary forest products such as sawlogs, logs for veneer, posts, pulpwood, and fuelwood. Twenty-four percent of the Nation's wood volume and 21 percent of total roundwood volume originates in the Northern United States.

Figure 28. **Disposition of wood removals in the Northern United States, 1996** (Smith and others 2001).

- Of the 3.5 billion cubic feet of roundwood products harvested in the Northern United States in 1996, the majority was from hardwood species. The top three roundwood products were sawlogs (36 percent), pulpwood (30 percent), and fuelwood (24 percent) (figure 29). Wood for composite products accounted for 6 percent of the total. Sixty-five percent of the pulpwood volume came from hardwoods, exceeding the national average of 43 percent (Smith and others 2001).
- Most roundwood is harvested from growing stock on timberland. Other sources include wood from sound dead trees, trees affected by rot, or trees located in fencerows,

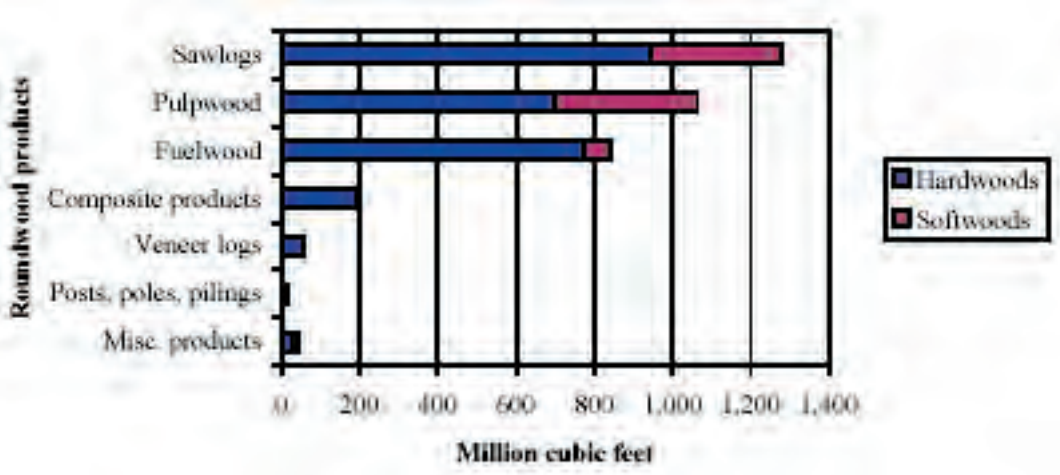

Figure 29. **Volume of roundwood products harvested in the Northern United States by species group, 1996** (Smith and others 2001).

windbreaks, wooded strips, and pastures. Black walnut trees in these situations, for example, can produce substantial economic returns. Fuelwood is the only major product category that is harvested predominantly from other sources; only 15 percent comes from growing stock (figure 30).

Figure 30. **Sources of fuelwood in the Northern United States, 1996** (Smith and others 2001).

Wood Product Production and Consumption

- The region has over 15,500 wood products, paper and paperboard, and wood furniture manufacturing companies and over 2,500 logging companies (table 10). While all of the States in the region have some wood-based manufacturing, a few States are leaders in the three industry components. Based on the 1997 value of shipments: (1) Indiana, Michigan, Minnesota, Ohio, Pennsylvania, and Wisconsin manufactured 65 percent of the region's wood products; (2) Illinois, Michigan, New York, Ohio, Pennsylvania, and Wisconsin led the paper products industry with a combined total of $44.3 billion, or 61 percent of the regional total; and (3) Indiana and Ohio each shipped over $1.6 billion in wood furniture, accounting for nearly a third of the regional total (USDC Bureau of the Census 2002).

Table 10. **Major timber harvesting and processing industries in the Northern United States** (U.S. Department of Commerce 2002).

Industry type	Number of establishments	Value added (thousands)	Total value of shipments (thousands)
Logging	2,685	$731,470	$1,641,603
Wood product manufacturing	7,348	11,105,245	26,340,977
Paper manufacturing	3,230	34,803,424	72,840,486
Wood furniture manufacturing	5,304	5,813,919	10,547,137
Total	**18,567**	**$52,454,058**	**$111,370,203**

- Total

pulpwood production for the States of Illinois, Indiana, Iowa, Maine, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Wisconsin increased 78 percent from 1965 to 1997, from 7.9 million to 14.1 million cords (figure 31, Howard 1999).

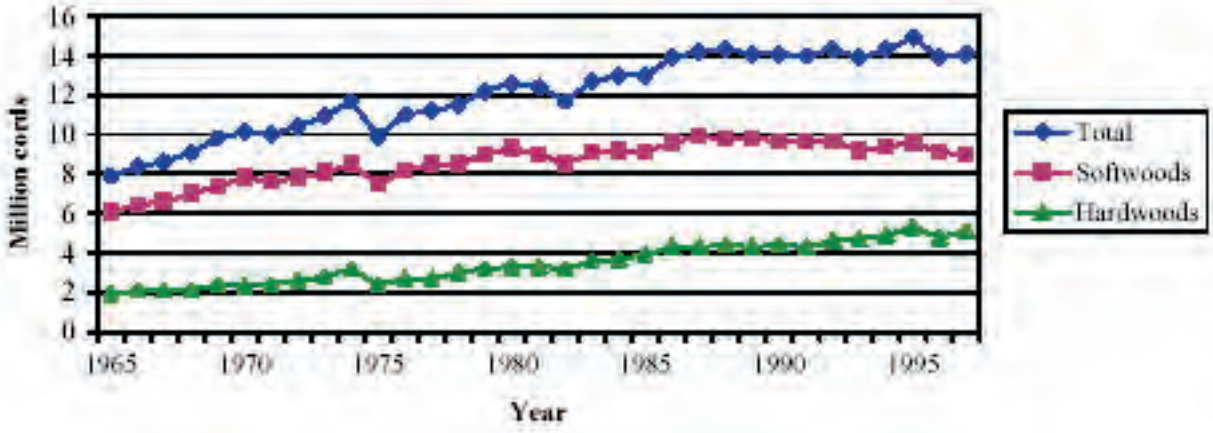

Figure 31. **Pulpwood production in 11 Northern States[1], 1965–1997** (Howard 1999).
[1]Illinois, Iowa, Maine, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Wisconsin

- Total consumption and consumption per capita increased for roundwood, sawnwood, wood-based panels, pulpwood, and paper and paperboard in the Northern United States between 1960 and 1990 (table 11).
- More wood products are being produced per unit of timber harvested today than in the past due largely to gains in the use of wood residue (chips, slabs, edgings, and planer shavings from sawmills and planer mills) and recycled paper (Ince 2000). In 1998, the U.S. industrial wood productivity—the quantity of wood product output produced per unit of roundwood input—based on industrial timber harvest was about 92 percent.

Table 11. **Forest products consumption in the Northern United States and U.S. rate of consumption per capita[1]** (USDA Forest Service 1996).

Forest products category and year	Estimated consumption for the Northern United States (thousand m^3 or MT)[2]	U.S. rate of consumption per capita
Roundwood		
1960	175,026 m^3	1.79 m^3
1990	240,148 m^3	2.15 m^3
Sawnwood		
1960	45,878 m^3	0.47 m^3
1990	59,260 m^3	0.53 m^3
Wood-based panels		
1960	4,600 m^3	0.05 m^3
1990	11,461 m^3	0.10 m^3
Wood pulp		
1960	13,013 MT	133 kg
1990	25,326 MT	226 kg
Paper and paperboard		
1960	18,835 MT	426 kg
1990	34,958 MT	689 kg

[1]Population figures based on census data were used to estimate consumption for the Northern United States. Consumption data originate from USDA Forest Service annual reports of forest production and consumption statistics.
[2] m^3 = cubic meters
MT = metric tons

Recycling

- Recycled fiber is an economical substitute for pulpwood for a large share of the paper and paperboard industries, but the two materials compete with one another for market share. When recycled fiber is used as a substitute for pulpwood, it can reduce wood use in the short run. Almost 50 percent of paper is recycled in the United States (AF&PA 1999).
- The paper and paperboard industries in the Northern United States use a higher proportion of recycled fiber than the rest of the Nation. The recovered paper utilization rate in the region averaged about 55 percent in 1996, compared with a nationwide average of 37 percent (AF&PA 1999). The utilization rate is the ratio of the tons of recovered paper used in paper and paperboard mills relative to the tons of finished product produced. Paper and paperboard mills in the Northern United States recycled 14 million tons of paper and paperboard in 1995.

Nonwood Forest Products

Nonwood forest products such as maple syrup, mushrooms, botanicals, and wreaths often have cultural and social values for families and communities in addition to market values.

- The ten major maple syrup producing States in the region (Connecticut, Maine, Massachusetts, Michigan, New Hampshire, New York, Ohio, Pennsylvania, Vermont, and Wisconsin) experienced an average of $34 million in annual sales between 1994 and 1998 (USDA National Agricultural Statistics Service 1995–1999).
- Records of the production and value of maple syrup are maintained by States and compiled by the USDA Forest Service's North American Maple Project.

Cultural, Social, and Spiritual Needs and Values

- When given a choice among four forest values, 59 percent of Northern U.S. residents surveyed identified clean air and water as the most important value to consider in the management of public forests, followed by scenic beauty, cultural and natural heritage, and wood products. On private lands, clean air and water also ranked first with 48 percent, but wood products ranked second, followed by scenic beauty, and cultural and natural heritage (figure 32, Cordell and Betz 2003).
- Forest land that provides opportunities for the protection of cultural, social, and spiritual values includes Federal forests and parks, State and county parks, natural areas, historic sites, and private land under conservation easements to public and private agencies and organizations.
- Specific land areas have spiritual meaning in some Native American cultures, such as burial grounds and offering sites. In general, however, forest-related spirituality is linked to untouched, cathedral-like, large trees, often called old growth forests.
- Forested landscapes are valued for residential use.

Recreation and Tourism

Outdoor recreation is an important basis for tourism and adds to the health and well-being of people of all ages and walks of life. Forests of the Northern United States provide

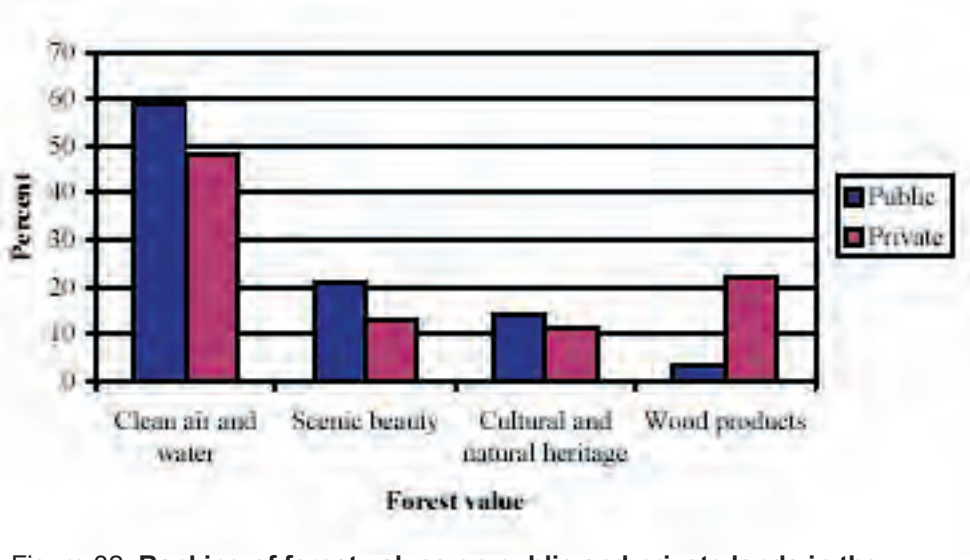

Figure 32. **Ranking of forest values on public and private lands in the Northern United States** (Cordell and Betz 2003).

opportunities for many different types of recreation.

- The Northern United States leads the Nation in the number of recreation activity days devoted to the enjoyment of scenery and wildlife in the forest setting. Recreation activity days measure recreation activities of any duration undertaken by forest users and generally include multiple activities that recreationists engage in during an outing (table 12). Many people enjoy walking, hiking, and camping in the woods. Some opt for strenuous activities such as backpacking, rock climbing, or river rafting; others prefer to travel in cars, off-road vehicles, or snowmobiles. Traditional activities such as big and small game hunting, and fishing are still enjoyed by many. Wilderness areas, nature centers, and both historic and prehistoric sites are popular destinations.
- It is difficult to determine the precise number of acres of forest land available for recreation by the general public versus that available to exclusive groups such as family

Table 12. **Recreation activity days occurring in forest settings in the Northern United States, 2000–2001** (adapted from Cordell and Betz 2003).

Activity	No. of days (millions)
View/photograph birds and other wildlife	3,188
View/photograph scenery	2,549
View/photograph flowers, trees, etc.	2,236
Walking for pleasure	1,281
Day hiking	749
Sightseeing	587
Picnicking, family gathering	545
Driving for pleasure	473
Mountain biking	445
Fishing (warmwater, coldwater, anadromous)	401
Visit a wilderness	319
Gather mushrooms, berries, etc.	249
Swimming	245
Drive off-road	239
Visit nature center	213
Visit a historic or prehistoric site	188
Hunting	158
Developed camping	135
Canoeing, rafting, kayaking	121
Backpacking, primitive camping	98
Downhill skiing, snowboarding	82
Horseback riding	74
Snowmobiling	72
Cross-country skiing, snowshoeing	52
Orienteering	23
Rock climbing, caving	23
Mountain climbing	22

or friends. The majority of public forest lands are open to the general public, whereas only a portion of private lands allow public access. Nationally, the percentage of nonindustrial lands open to the public has decreased from 29 percent in 1977 to about 11 percent in 2000–2001. The Northern United States has the Nation's highest percentage of private nonindustrial land open to the general public for recreation (13 percent) (Cordell and others, Cordell and Betz 2003).

Recreation Facilities

- The Northern United States had 144 million acres of forest potentially available for outdoor recreation in 1997, an average of about 1.2 acres per resident compared to a national average of 2.3 acres (Cordell and Betz 2003, Smith and others 2001).
- The bulk of forest land available for recreation in the Northern United States is in private ownership (63 percent). The remainder is managed by Federal agencies (9 percent), State and local governments (19 percent), and industrial landowners (8 percent).
- Amenities on federally administered lands included 2,150 miles of national recreation trails, 546 miles of wild and scenic rivers, 285,000 acres in national recreation areas, and 1.4 million acres in wilderness areas in 1987 (Cordell and others 1990).
- In the Northern United States, 278 out of 428 Federal recreational facilities and 939 out of 1,249 State parks occur in forested areas , including facilities for camping, hiking, picnicking, and snow sports. There are an estimated 1,978 public and private campgrounds and 240,405 campsites in forested areas (Cordell and Betz 2003).
- The number of campgrounds and campsites in forested areas is only a fraction of the total. For example, Leefers and Vasievich (1999) identified 1,854 campgrounds in Michigan, Wisconsin, and Minnesota alone hosting 147,585 campsites. Just over half of the campgrounds and nearly two-thirds of the total campsites were in private ownership, while only 9 percent of the campgrounds and 3 percent of campsites were located in national forests. State recreation areas had the most campsites per campground.
- Trends indicate that trails and green space will be used more heavily in the future, especially in locations near large population centers.

> The decline in recreation opportunities on private lands due to conversion to other uses and restricted access could be addressed through cooperative public/private efforts.

- Water- and land-based recreation activities in the United States have a net economic value ranging from $15 to $155 per person per day; however, most range in value from $20 to $30 per person per day (USDA Forest Service 1997a).

Investments in the Forest Sector

- About 95 to 99 percent of tree regeneration in the Northern United States is accomplished through natural seeding and sprouting. The remaining 1 to 5 percent is accomplished by tree planting. In Federal Fiscal Year 1999, public and private nurseries produced 138 million trees with a market value of approximately $27 million. About $22.5 million was invested in tree planting for reforestation (Overton 2001).

- Forest management and improvement is carried out for a number of purposes, including wood production, wildlife enhancement, watershed protection, protection from destructive grazing, and fire, insect, and disease prevention. The total Federal investment in forest management and improvement was $12.7 million in Fiscal Year 1999 (table 13).

Table 13. **Level of investment in forest growing and improvement in the Northern United States, FY 1999** (USDA Forest Service 1999b).

Treatment	Acres	Cost per acre	Investment
Timber stand improvement	81,946	$55.00	$4,507,030
Wildlife enhancement	141,498	20.00	2,829,960
Watershed protection	237,391	15.00	3,560,865
Fire prevention	181,830	5.00	909,150
Insect and disease prevention	183,188	5.00	915,940
Protection from destructive grazing	9,554	2.50	23,885
Total	**835,407**	—	**$12,746,830**

- The Federal investment in forest health management and monitoring in the Northern United States was $10.2 million in 1999 and rose to $15 million in 2000 due to changes in pest suppression needs, specifically, the southern and western advancement of the gypsy moth (USDA Forest Service 1999b, 2000).
- The rate of return on forest land for timber value in the Northern United States remained relatively stable between 1952 and 1997, but is consistently lower than the national average (figure 33).

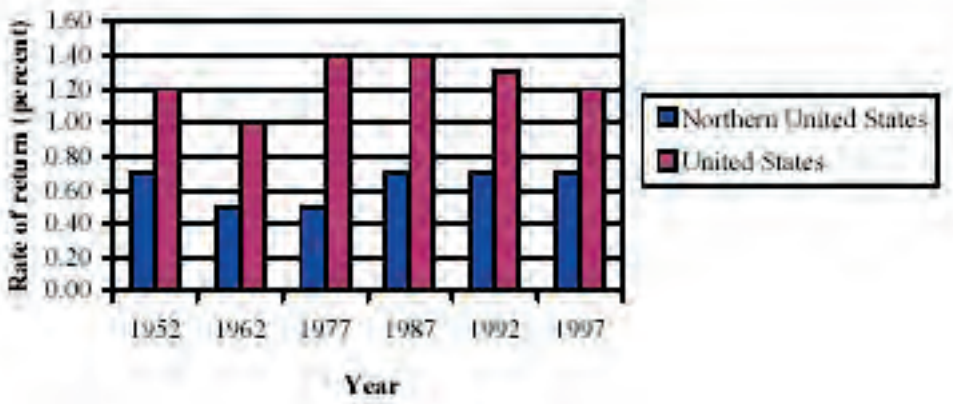

Figure 33. **Estimated rates of return from timber production to timber assets, 1952–1997** (USDA Forest Service [In press]).

- Investments by the wood products and paper industry in new capital expenditures, and pollution abatement and control in the Northern United States were estimated at $6.5 billion in 1994 (AF&PA 1999).

Investments in Research and Education

- In 2000, $76.4 million was invested in forestry research at 33 universities in the Northern United States, up from $67.8 million in 1995 (figure 34). Fifty-two percent of this funding was provided by State governments and 31 percent by Federal government sources. Almost half of the Federal support ($10.9 million) was from USDA Cooperative State

Research Extension and Education Service funding sources, including the McIntire-Stennis Cooperative Forestry Research Program that funds forestry graduate research. Other Federal sources of funding include Agricultural Experiment Station Act of 1887 (Hatch Act) funds for State agriculture experiment stations and forestry school research, and Renewable Resource Extension Act grants.

- The Forest Service provides each of the Northern States an annual allocation of $10,000–$15,000 for conservation education.

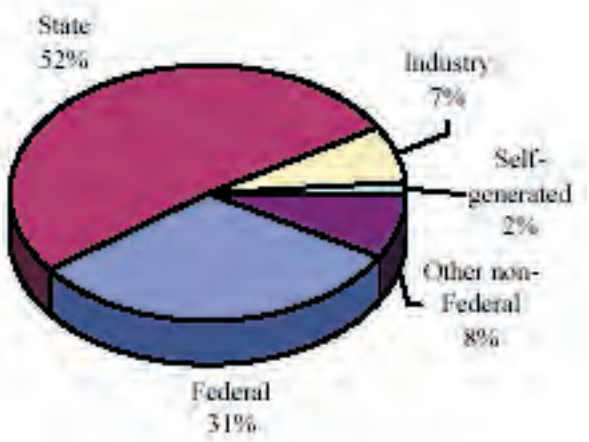

Figure 34. **National investment in forestry schools, 2000**. Of the $76.4 million invested in forestry schools in 2000, the largest portion came from State governments (Norland 2003).

Employment and Community Needs

- Timber processing industries provide income and employment opportunities, and contribute to the economic diversity of the communities where they are located. The logging, wood products, paper and paperboard, and wood furniture industries in the Northern United States employed 612,000 people in 1997 (table 14).

Table 14. **Employment, payroll, and hourly wages for major wood processing industries in the Northern United States, 1997** (U.S. Department of Commerce 2002).

Industry	Number of employees	Annual payroll (thousands)	Average wages per hour for production workers
Logging	12,288	$259,876	$12.70
Wood product manufacturing	196,485	4,890,711	11.26
Paper manufacturing	302,710	11,413,062	15.60
Wood furniture manufacturing	100,855	2,625,074	11.26
Total	**612,338**	**$19,188,723**	—

- Employment levels reflect the nature of the end product more than the number of establishments. Industries producing secondary products such as furniture tend to have more employees than industries producing primary products such as lumber. Higher average compensation in the paper industry (over twice as much as the lumber industry) reflects the need for better-trained employees, mill ownership, degree of unionization of the labor force, and relatively stable levels of end product consumption.
- The Northern United States accounted for nearly a third of the Nation's workers in agriculture, forestry, fishing, and related fields in 1998. The most highly paid categories of forestry occupations are foresters, conservation scientists, forest fire inspectors, and fire prevention specialists. There are considerable disparities in wage rates for similar jobs from State to State (USDL Bureau of Labor Statistics 2001a).

- Most Federal and State forestry positions are technical, professional, and managerial. Forestry technicians are paid the least, and managers the most. Pay for experienced field foresters varied across States from a high of $58,800 to a low of $28,000 in 1998. A maxim in forestry is that work gets done in the field; however, the average difference in annual pay between entry level and experienced field or service foresters among the 20 States is only $11,136. The premium for experience among the States ranged from $5,000 to $23,800 (NASF 2001).
- Timber industry jobs in the region are declining in spite of increased logging due to a number of factors: mechanization is enabling more work to be done by fewer people, competition is shifting jobs to other regions of the world, and improvements in engineering and technology have decreased society's reliance on wood manufacturing. As with other manufacturing jobs, some wood manufacturing jobs have been replaced by recreation, tourism, and other service sector jobs. On a local and regional basis, however, wood manufacturing continues to provide an important component of community and economic stability (NWF-NNRC 1996).

Worker Safety

- Safety has improved in many forest products jobs in the last decade, although logging continues to be one of the most dangerous professions. Death and injury are frequently associated with jobs such as felling, limbing, bucking, and choke setting. Between 1992 and 1996, 172 loggers are known to have died in the Northern United States. Injury rates for occupations in key forest sectors are higher than the national average (USDL Bureau of Labor Statistics 2001b,c,d).

Criterion 7

Legal, Institutional, and Economic Framework for Forest Conservation and Sustainable Management

Criterion 7. Legal, Institutional, and Economic Framework for Forest Conservation and Sustainable Management

Societal Trends Affecting Forest Conservation and Sustainable Management

Forest conservation and sustainable management are affected by dynamic environmental, social, and economic conditions and changing values.

- The rapid pace of social, demographic, and technological change combined with government budget cutting, restructuring, and personnel reductions, however, stresses existing public institutions in the Northern United States and across the country. Some key external considerations are population increases; increasing cultural diversity; rapid changes in communication technology; an environment in which capital, products, and information flow more quickly and freely across State, regional, national, and international borders; and evolving public attitudes toward management and investment in forest resources. These changes have made monitoring human-natural resource interactions more complex. There is still work to be done, especially in the arena of social and economic indicators.

Landownership in the Northern United States

- The majority of forest land in the Northern United States, approximately 130 million acres (78 percent), was privately owned according to a 1994 estimate, reflecting an increase of 16 million acres since 1978 (figure 35, Birch 1996).

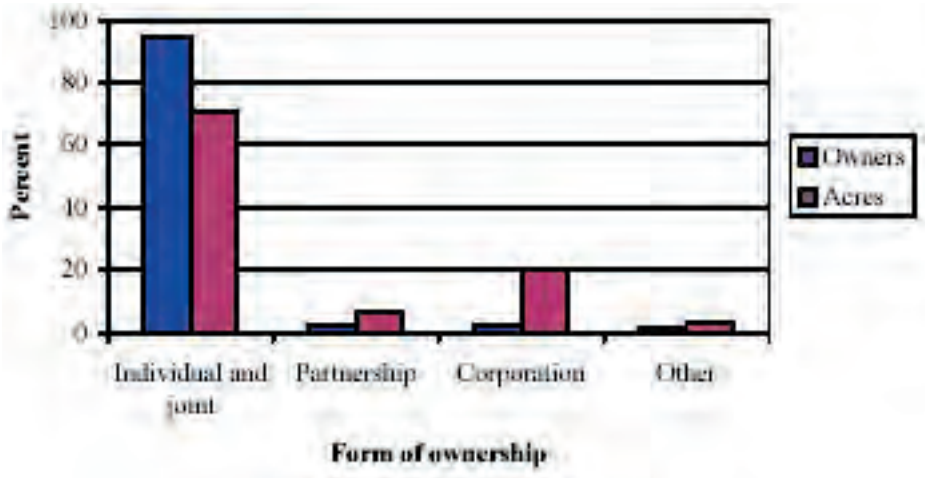

Figure 35. **Distribution of private ownerships in the Northern United States, 1994.** Individuals own the bulk of private forest land in the Northern United States (Birch 1996).

- Privately owned forest land contributes to the economy while providing recreation, forest products, biological diversity, wildlife habitat, and clean water. It is in the public's best interest for private property owners to have a sound stewardship ethic and practice long-term forest management.
- There were approximately 75 million acres of publicly owned land in the Northern United States in 1999 (Carpenter 1999), about half of which is forested (Birch 1996). Public lands

are administered by agencies of Federal, State, county, and municipal government. State forestry agencies administer nearly one-third of the public land acreage. The USDA Forest Service manages the majority of Federal land, almost 12 million acres, in the Northern United States (figure 36, USDA Forest Service 1997b).

Public lands contribute many of the same benefits as private lands, as well as offering additional amenities. For example, public lands may contain large blocks of contiguous forest that support primitive recreation, wilderness experiences, and habitat for wildlife that depend on interior forest. They also provide reference sites for forest health monitoring and long-term ecological studies, and opportunities to showcase sustainable forest management.

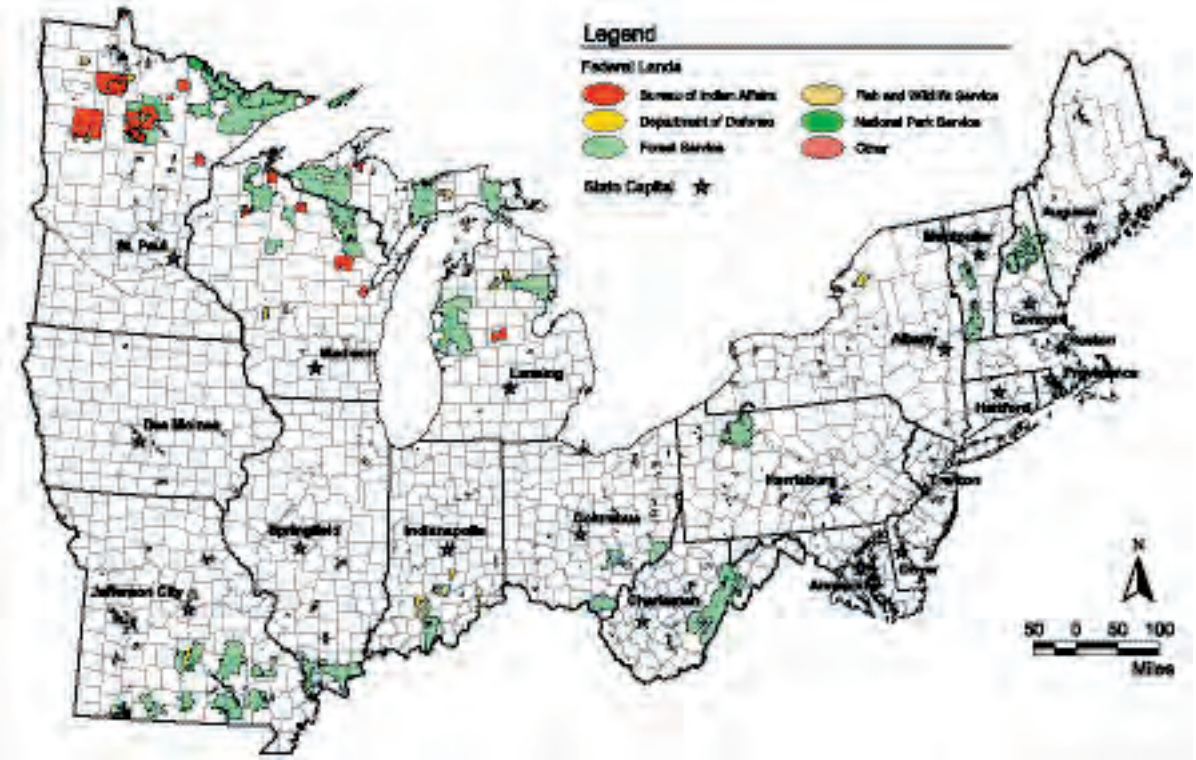

Figure 36. **Federal land holdings in the Northern United States**. The USDA Forest Service holds the most land among Federal agencies in the Northern United States—nearly 12 million acres.

- Public education and program delivery to forest landowners in the Northern United States is complicated by the fact that an increasing number of individuals own small parcels of forest land. National studies estimate that services may reach 5 percent of landowners, with the potential to affect 15–20 percent of nonindustrial private forest land acres (USDA Forest Service 1997a). There were an estimated 3.9 million private forest land ownerships in the Northern United States in 1994 (Birch 1996).
- People own land for a variety of reasons. For nearly 42 percent of the private forest landowners in the Northern United States, the primary reason for owning forest land is because it is part of their farm or residence. Another 10 percent cited utilizing their woodlands for farm or domestic use as the most important reason for holding forest

land. Recreation and aesthetic enjoyment is the primary reason for 29 percent of owners. Only 1 percent say their land is owned or managed primarily for timber production, but these owners control 19 percent of the private forest land (Birch 1996). Nationwide, nonindustrial private forest lands are producing half of the country's domestic timber supply (Sampson and DeCoster 1997).

- Private landownership patterns are shifting. The number of private landowners, including the number of retired owners, is increasing, and average land tenure and the number of owners tied to the land for income are decreasing (Birch 1996).
- A trend that may have implications for forest sustainability is an increase in forest land ownership by institutional investors such as pension funds, insurance companies, banks, endowments, and foundations (Binkley and others 1996). These organizations often have the capital to invest in and manage forest land, and the ability to retain capital over the decades it takes to realize profit from forestry investments if they chose to do so.

Laws, Regulations, and Guidelines

The legal framework is set through actions of the legislative, executive, and judicial branches of government.

- An extensive legal framework supports the goals of sustainability in the United States and the Northern United States. The processes and procedures developed to implement the numerous laws and regulations, however, are sometimes unduly complex and counterproductive.
- Federal authority—Many Federal laws affect forestry. Applicable national laws and regulations may be associated with the protection of public benefits from forests and the prevention of damage to natural and cultural resources such as wetlands, water and air quality, wildlife, and threatened and endangered species, and historic sites. Tax, business, health, and safety laws and regulations also affect private forestry, forest-based industries, and community sustainability.
- State authority—Laws and regulations developed at the State level are more common today than in the past. Advocates for State regulation see it as more pragmatic than Federal or local regulation.
- Local authority—Counties, cities, and towns have authority to regulate land use and activities (table 15). Municipalities cannot usurp regulatory rights reserved by the State but can pass laws more restrictive than State law.

Table 15. **Counties, cities, and towns in the Northern United States with the authority to regulate land use and activities** (Ellefson and others 1995).

State	Counties	Municipalities	Townships
Delaware	1 of 3	—	—
Illinois	—	1,000 of 1,200	—
Maryland	20 of 23	—	—
Michigan	—	—	10 to 15 of 1,200
Minnesota	1 of 87	—	—
New Jersey	15 of 21	300 of 567	—
New York	—	70 of 900	—
Pennsylvania	—	13 of 420	—
Vermont	—	2 of 251	—
Wisconsin	2 of 72	3 to 4 of 1,500	—

- The USDA Forest Service identified four national trends affecting property rights (USDA Forest Service 1997a):
  1. There is an increase in the regulatory, legislative, and judicial actions that affect property rights, either expanding or diminishing them.
  2. Changes in patterns of ownership and use are significant.
  3. Economic valuations are being extended to new types of natural resources (e.g., landowners lease land for hunting, States subsidize landowners to protect specific resources, collectors pay for permits to collect nontimber forest products).
  4. There is increasing autonomy for Native American tribes.
- Many Federal, State, and local laws are intended to conserve and protect special environmental, cultural, social, and/or scientific values. Federally designated special areas include Research Natural Areas, Wilderness Areas, Wild and Scenic Rivers, and American Heritage Rivers. A number of States have been leaders in the development of State systems of natural areas.
- Private industrial owners also have opportunities to conserve special areas and values. One of the primary principles of the American Forest and Paper Association's Sustainable Forestry Initiative is the management of forests and lands of special significance (e.g., biologically, geologically, or historically significant) in a manner that takes into account their unique qualities (AF&PA 1994).
- A variety of legal instruments exist to preserve specific forest conditions regardless of ownership, including conservation easements, placing lands in private and public land trusts, marketing of rights traditionally associated with property (e.g., development or pollution), debt-for-nature swaps, and other types of land trades (USDA Forest Service 1997a). These transactions are enacted on a willing buyer, willing seller basis.
- The USDA Forest Service's Forest Legacy Program was authorized to protect environmentally important forests from conversion to nonforest uses. From its initiation in 1992 to 2002, 130,000 acres were protected in the Northern United States. Protection is usually accomplished with conservation easements, but tracts can be purchased outright. States and other organizations contribute to a number of conservation easement programs that protect forested and other lands.
- Public laws, regulations, and policies governing the management of land for nonforest uses or other social benefits can have unintended consequences on the forest resource (e.g., land drainage for development and fire suppression for public safety).

Institutions That Support the Conservation and Sustainable Management of Forests

Both government and nongovernment organizations bring institutional capabilities to bear in implementing laws, regulations, and guidelines on public and private lands. A variety of institutions exist to meet this goal, including forestry agencies, programs for private forest landowners, forest certification, associations, land trusts, institutional investors, and the forest industry.

- A variety of Federal programs exist that support State and community efforts to conserve or protect resources critical to public health, safety, or welfare (table 16).

Table 16. **Major Federal forest conservation programs**. Federal programs offer technical assistance at the landowner, community, State, and regional level.

Agency[1]	Program	Description
USFS	Forest Stewardship	Focuses on management of nonindustrial private forest land; encourages preparation of land management plans for multiple uses.
USFS	Forest Land Enhancement	Replaces the Stewardship Incentive and Forestry Incentives Programs in FY 2003. Focuses on management plan development and cost-share activities on nonindustrial private forest land
NRCS	Environmental Quality Incentives	Develops and implements management plans to protect and conserve soil, water, and related resources.
NRCS	Conservation Technical Assistance	Focuses on land management plans primarily for farm-forest owners.
NRCS	Conservation Reserve	Converts unsuitable cropland to permanent vegetative cover.
USFS	Forest Legacy	Protects forest lands threatened with conversion to nonforest uses by purchasing conservation easements or fee titles from willing private landowners.
NRCS	Wildlife Habitat Incentives	Offers financial incentives to develop fish and wildlife habitat on private lands.
USFWS	Partners for Fish and Wildlife	Offers technical assistance to restore and conserve wildlife habitat.
NRCS	Wetlands Reserve	Protects wetlands through easements and total coverage of wetland restoration costs.
NRCS USFS	Public Law–566 Small Watershed Incentives Program	Focuses on protecting water quality. Assists communities in developing watershed management plans on watersheds less than 250,000 acres.
USFS	Cooperative Forest Health Management	Provides technical expertise to detect, evaluate, and monitor forest health and to suppress or eradicate forest insects and disease.
USFS	Fire Management	Develops State programs to protect lives, property, and natural resources from uncontrolled wildfires.
USFS	Economic Action	Strengthens community economic conditions through programs such as Rural Development and Wood in Transportation.
NRCS USFS	Resource Conservation and Development	Promotes the conservation, development, and utilization of natural resources to improve economic conditions and enhance the quality of life in designated multicounty geographical areas.
USFS	Urban and Community Forestry	Offers technical assistance on urban tree health, protection, and maintenance, and promotes management of forest and related resources in populated areas.
USFS	State Forest Resource Planning	Promotes the development of comprehensive State forest resource plans for the long-term benefit of society and the natural resources people depend upon.

[1]NRCS = USDA Natural Resources Conservation Service
USFS = USDA Forest Service
USFWS = U.S. Fish and Wildlife Service

- Federal and State agencies provide infrastructure for forestry technical assistance in the Northern United States. The USDA Forest Service provides service through its State and Private Forestry, Research, and National Forest branches. There are 17 national forests and grasslands in the Northern United States.
- Public institutions are responsible for developing and maintaining infrastructure on public lands. It is recognized that the maintenance of roads, trails, and watershed improvements is backlogged, and much attention needs to be focused in the near future to maintain the integrity of forest resources on public lands.
- In developed areas, community organizations and agencies are compiling inventories of restoration needs, including the restoration of wetlands, shorelines, floodplains, various vegetative communities, terrestrial and aquatic habitats, and reclamation of various brownfields (areas contaminated by toxic materials) and gravel pits.
- Industry infrastructure is a factor affecting the flow of goods and services from forest lands. The challenge in assessing industry infrastructure is determining the proper balance between manufacturing capacity and the ratio of forest growth to removals, and the appropriate balance between industry profitability and community stability. Key considerations in determining the efficiency of industry infrastructure include the degree of efficient use of raw materials, manufacturing by-products, and recycled materials, and the energy costs associated with the transportation of materials and products.
- In a recent review of public programs and options for private forestry, Sampson and DeCoster (1997) point out that Federal programs supporting private forestry are not keeping pace with the country's changing demographics. They recommend expanding service to rapidly developing communities and suggest more sophisticated marketing to target messages to particular audiences. More detailed information on forest landowners and the relationship between communities and the forest resource may be needed to effectively implement such a strategy; however, a fear of marketing by policy leaders was cited as the major impediment to adopting these changes.
- There were approximately 831 local and regional land trusts operating in the Northern United States in 1998, a 50 percent increase from 1988 (Land Trust Alliance 1998). Of existing trusts, roughly 46 percent identified forests as one target of their efforts; 12 percent identified timberland. The Nature Conservancy, the Trust for Public Land, the Conservation Fund, Ducks Unlimited, and the American Land Conservancy are among the well-known national trusts working to protect forest land.

Forest Certification

Probably the newest emerging institutions are those associated with forest certification, a process to verify that wood products come from sustainably managed forests. Participation in forest certification programs is voluntary. Certification can be applied to land, forest management activities, or resource managers. Forest certification claims are verified on a first-party, second-party, or third-party basis.

- The Northern United States has the most third-party certification activity nationwide. As of February 1, 2000, approximately 5.1 million acres were certified in the Northern United

States, representing 91 percent of the national total. Pennsylvania had the largest certified acreage in the region (2.3 million acres), followed by Maine (1.0 million acres), New York (717,000 acres), Minnesota (585,000 acres), Wisconsin (252,000 acres), and Michigan (155,000 acres) (Hansen and Bratkovich 2000).

- Manufacturers and retailers may be certified based on their ability to track the chain of custody of products from sustainably managed lands to the market. Ninety-three companies and organizations (42 percent of national total) are certified for chain of custody maintenance in the Northern United States. Pennsylvania has the most with 15, followed by Maine (13), Vermont (11), and Wisconsin (10).
- There are five Forest Stewardship Council certified forest managers the Northern United States (Hansen and Bratkovich 2000).

Planning and Public Involvement

Forest resource management plans identify resource and management needs and opportunities, and priorities for action. New plans are necessary when public expectations change and when new information invalidates previous assumptions. Planning can be strategic, tactical, or operational. Many strategic plans are developed for a particular branch or department of an organization; tactical plans can be developed by department, division, or program area, or for designated management units. Operations are dealt with at landscape and local scales, and on a project-by-project basis.

- Federal law requires national forests and grasslands to prepare and periodically revise their land and resource management plans.
- Each of the 20 Northern States has developed at least one comprehensive State forest resource plan under the Federal Cooperative Forestry Assistance Act of 1978. Many plans, though, need to be updated.
- The institutional framework providing for education and public participation includes Federal and State government agencies and services, environmental groups, nonprofit educational foundations, forest products consortia, professional consultants, tribal governments, and facilitation organizations.
- The present trend for forestry agencies is to invite the public to participate in all steps of the decisionmaking process, whether or not it is legally required. Steps include issue identification, assessment, planning, and developing policy and management alternatives.
- Institutional barriers to successful public involvement in public agency projects include conflicting laws, lack of funds to implement preferred solutions, professional resistance to nontraditional approaches, legal or administrative rules that constrain managers, and at times, a lack of staff experience in facilitating resolutions of conflicting values and objectives among stakeholders.

Human Resources

- The importance of advanced analytical skills is increasing as the public pushes natural resource managers to better integrate environmental, social, and economic information.

- The USDA Forest Service employed just over 3,000 permanent workers in the Northern United States at the close of Federal Fiscal Year 2002.
- State forestry agencies in the 20 Northern United States and the District of Columbia employed a total of just over 3,140 permanent employees and 1,900 seasonal or temporary employees in 1998 (NASF 2001). Their staff sizes are proportionate with the amount of forest land in each State and the complexity of issues and programs. Several State forestry agencies face the challenge of retaining experienced field foresters and managers due to State salary structures and caps. Many service foresters are lured to forest industry or private consultation practices, where the salary potential is often much greater.
- There are 984 county conservation districts in the Northern United States. Of the 755 districts responding to a 1998–1999 survey, 88 have a forester on staff and 23 employ forestry technicians (Kershner 2000). However, 207 districts mentioned that other conservation district staff work on forestry issues.

Professional Credentials

- Standards of professional performance are often set in licensing, registration, and certification programs. Eight States in the Northern United States administer these types of programs, as do some private organizations (table 17).
  - **Registration** is a procedure requiring a person to meet certain standards before being allowed on a list, usually compiled and administered by a government agency.
  - **Licensing** is a legal procedure that requires a person to meet certain standards as a prerequisite to granting permission to practice in their profession.
  - **Certification** is a voluntary procedure in which the certifying organization attests that a person has attained a certain level of competence. The Society of American Foresters and the Association of Consulting Foresters are examples of organizations that offer private forester certification programs.

Table 17. **Forester registration and licensing programs**. Eight States in the region have forester registration or licensing programs (Society of American Foresters 2001).

States	Program type	
	Voluntary registration	Licensing
Connecticut[1]		X
Maine		X
Maryland		X
Massachusetts		X
Michigan	X	
New Hampshire		X
New Jersey		X
West Virginia	X	

[1]Called mandatory certification in statute.

Extent to Which Economic Policies and Measures Support the Conservation and Sustainable Management of Forests

The economic framework is an important component in conservation and sustainable forest management efforts. Markets influence the flow of goods and services and the allocation of the various products that are produced from a given forest area. Economic policies influence the velocity of product flow and whether that flow comes from public or private forest lands.

However, traditional economic measures have difficulty capturing the unique diversity of production, its site-specific capacity characteristics, and the value of its nonmarket benefits.

- Calls for acquisition of more public land are sometimes matched by concerns over reduction in the municipal tax base, the loss of working forests, inadequate public funding, and the inability of the public sector to effectively manage more land with less staff and less resources.
- Private management decisions are often constrained by short-run considerations and market signals, while returns from forestry investments tend to be long term.
- Investment, taxation, and forest management policies and programs are established or modified to influence people's decisions and behavior concerning their land. They are intended to encourage or discourage actions and to offer incentives to meet private or public objectives. These mechanisms can alter choices and have economic implications to the individual owner and impacts on the broader public.

Reforestation tax credits can be applied against Federal income tax liability for expenses incurred for reforestation (Public Law 96–451).

- Federal agencies offer conservation programs to spur investment in the management and retention of forests. Many of these programs are geared to the reforestation, planning, and management of forest lands or to the conversion of marginal agricultural land to forest uses. Programs include the USDA Forest Service's Forest Stewardship and Forest Land Enhancement Programs, and the USDA Natural Resources Conservation Service's Conservation Reserve Program.
- Forestry program expenditures in 1998 in the Northern United States are estimated at $273 million. An estimated 59 percent of forestry program funding support in the Northern United States is provided by the State, about 31 percent is from revenue, almost 7 percent is from the Federal government, and less than 4 percent is from other government sources (NASF 1998).
- Low-interest loans and grants are another investment mechanism that fosters sustainable forest use. The USDA Forest Service's Rural Development Program offers financial and technical assistance to help communities and small forest-based businesses develop and succeed. These public investments are intended to infuse capital to support start-up business development, encourage rural economic development and diversification, and help retain forest-based industry in rural communities.
- Trends in property, capital gains, and estate tax policies may be more important than income taxes for maintaining a forested land base (Birch 1996, Sampson and DeCoster 1997). When landowners reforest agricultural land it may become subject to higher property tax levels. Capital gains taxes can provide incentives to reforest land, but can hamper long-term management strategies. A landowner who holds forest land for profit is subject to capital gains taxation at harvest. Estate taxes may force heirs to sell land to developers or make unplanned harvests to pay the tax bill.

Some States have adopted use-value and other preferential assessments for forest use as well as agriculture. Property taxes are reduced to reflect the lower costs of community services absorbed by the land use and the benefits it returns to the municipality. For example, Pennsylvania's Farmland and Forest Land Assessment Act ("Clean and Green Act") offers lower taxes for land in productive open space.

International Trade

The United States is the world's single largest international trader and "the U.S. economy is among the most open and transparent in the world" according to members of the World Trade Organization Trade Policy Review Body (World Trade Organization 2001, p. 1; table 18).

Table 18. **Free trade agreements and restrictions.** The United States generally supports free trade policies related to forest products, though there are some restrictions in place.

Free trade legislation	Description
Agreements	
General Agreement on Trade and Tariffs (GATT)	International agreement first negotiated in 1947. Since 1995, the updated GATT serves as the World Trade Organization's principal rule book for trade-in goods including forest products.
North American Free Trade Agreement (NAFTA)	The 1994 agreement to remove most barriers to trade and investment among the United States, Canada, and Mexico. Incorporates most provisions of the 1989 U.S-Canadian Free Trade Agreement (FTA).
International Tropical Timber Agreement (ITTA)	International agreement among producers and consumers of tropical timber on trade and conservation issues. Has no price regulation or market intervention provisions. Created the International Tropical Timber Organization in 1983.
Free Trade Areas of the Americas (FTAA)	Negotiations began in 1994 to liberalize trade among 34 countries of the Western Hemisphere, including investment regimes and competition policies.
Restrictions	
Final rule of the USDA Animal and Plant Health Inspection Service	Details acceptable treatments and handling procedures for importing logs, lumber, and other manufactured wood articles in order to protect the U.S. domestic timber resource from pests. (Canada and Mexico are exempt.)
Forest Resources Conservation and Shortage Relief Act of 1990 (FRCSRA)	Prohibits export of unprocessed logs from federally owned lands west of the 100th meridian in an effort to support forest-dependent communities (does not affect the Northern United States).
1996 U.S.-Canada Softwood Lumber Agreement	Agreement to cap tax-free Canadian exports to the United States at 14.7 billion board feet annually. Expired March 2001.

- Overall production and consumption of forest products has increased in the United States since 1965, and demand for wood products exceeds domestic production. Forest product imports increased from 1,604 million to 4,029 million cubic feet (roundwood equivalent) from 1965 to 1997 to make up the difference. The United States imports most types of forest products, including structural panels and lumber. Nearly 83 percent of log imports are from Canada (Howard 1999).

- U.S. exports have also increased during the same timeframe, from 544 million to 2,236 million cubic feet (roundwood equivalent). The majority of U.S. lumber exports go to Japan, Canada, and the European Union (Belgium-Luxembourg, Denmark, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Trieste, and the United Kingdom) (Howard 1999).
- United States exports of pulpwood, paper, paperboard, and converted paper products to the Free Trade Area of the Americas have grown steadily, amounting to $6.9 billion in 1998 (Canada and Mexico accounted for $5.3 billion of that total). Tariffs on paper products, however, are high (Smith 1999).
- A 1997 study of wood flows in New York, Vermont, New Hampshire, and Maine found that 22 percent of the roughly 14 million cords of wood harvested in the region crossed a State line or international boundary before it was used (The Irland Group 1999). The majority of products exported from these States were of high value (e.g., softwood logs), while imports were low-value products (e.g., pulpwood and biomass fuel).

Capacity to Measure and Monitor Changes in the Conservation and Sustainable Management of Forests

- Within the United States, a national Roundtable on Sustainable Forests has been formed consisting of Federal, State, and private stakeholders to promote sustainable forest management. The roundtable places strategic focus on implementing the Montreal Process criteria and indicators (C&I) as a means of monitoring changes in the conservation and sustainable management of forests. A technical working group has been formed to develop a national set of protocols to implement C&I, establish a collaborative national arrangement for data collection and reporting of C&I, and help guide development of a national report on sustainable forest management by 2003 (Roundtable on Sustainable Forests 2002).
- The USDA Forest Service's Northeastern Area and the Northeastern Area Association of State Foresters determined that C&I can provide relatively complete, accurate, and unbiased information on forests, and they are committed to supplementing national C&I assessments at the regional level. The *Sustainability Assessment Highlights for the Northern United States* represents results from the Northeastern Area's first effort to use C&I. The assessment builds on information provided by the Forest Service's Forest Inventory and Analysis Program, Forest Health Monitoring Program, and other information readily available to the public. More work is needed to address data gaps and inconsistencies in measures used.
- The Northeastern Area and the Northeastern Area Association of State Foresters are working with the Northeastern Forest Resource Planners Association on measurement guidelines for 18 regional scale indicators that will be used in future sustainability assessment reports (USDA Forest Service 2002b).
- A survey of significant sustainability projects, including national efforts as well as regional, State, county, and municipal efforts within the Northern United States, yielded 54 projects, 9 of which draw directly from the Montreal Process criteria (USDA Forest Service 2002b).

- Remote sensing products are increasingly used to inventory conditions and trends important to forest sustainability such as the extent, type, age, and health of forests. Computer-based geographic information systems allow for the analysis of more complex information with higher reliability, consistency, and accuracy than in the past. Changing technologies and inventory methodologies, however, affect the availability and accuracy of trend analyses.
- Public and private entities throughout the Northern United States conduct forest inventory and monitoring at a variety of scales. Examples at the Federal level include the USDA Forest Service's Forest Inventory and Analysis Program, Forest Health Monitoring Program Detection Surveys, and North American Maple Project.
- Data compatibility is an important issue for management units that share ecosystems, watersheds, or program implementation responsibilities. The USDA Forest Service in the Northern United States and the Northeastern Area Association of State Foresters are cooperating with national efforts to identify common measurement and reporting protocols that relate to sustainability. Many of these will provide for data compatibility at the regional and State level.

Capacity to Conduct and Apply Research and Development

- The institutional infrastructure of Federal, State, and private research and educational facilities is well developed in the Northern United States. A variety of institutions conduct research beneficial for forest sustainability. The capacity of these organizations to conduct and apply research depends on the expertise, equipment, and facilities available. Equally important are the institutional arrangements and incentives that direct individual researchers to respond to society's needs.
- Two of seven USDA Forest Service research stations are located in the Northern United States—the North Central Research Station and the Northeastern Research Station. These stations administer about 40 project work units among 18 field offices as well as 22 experimental forests and watersheds (table 19).
- Historically, forest research includes watershed management, mined-land reclamation, wildlife habitat needs and management, forest genetics, forest silviculture, insect and disease detection and treatment, forest products, harvesting and utilization, economics and marketing, recreation, urban forestry, and forest inventory. More recent issues include acid deposition, global climate change, and international forestry. The majority of forest industry research, however, is directed to the development, processing, marketing, and use of forest products rather than basic scientific or management research (Ellefson and Ek 1996).
- The forest research community is looking for linkages and integrating principles among individual disciplines, such as systems-based approaches. Ecological classification and mapping is used in the Northern United States to frame research into ecological processes and functions.
- Research agencies in Federal and State government and in private industry have been affected by the widespread downsizing and restructuring common across the country in the

Table 19. **Experimental forests and watersheds**. The USDA Forest Service maintains 22 experiment forests and watersheds for long-term research into forest and watershed management throughout the Northern United States. The region is served by the Forest Service's Northeastern and North Central Research Stations.

Location	Research Work Unit (RWU)	Research focus
	Northeastern Research Station	
Bartlett, NH	Ecology and Management of Northern Forest Ecosystems	Long-term research and demonstration of sustainable silvicultural and management systems for northern hardwood forests
Fernow, WV	Sustainable Forest Ecosystems in the Central Appalachians	Long-term research and demonstration of sustainable management practices for central Appalachian hardwood forests; impacts of forest management and pollution on watersheds
Hubbard Brook, NH	Ecological Processes: a Basis for Managing Forests and Protecting Water Quality in New England	Part of the U.S. Long Term Ecological Research Network; long-term research on the interactions of forest management, ecosystem processes, and watersheds
Kane, PA	Understanding and Managing Forest Ecosystems of the Allegheny Plateau	Long-term research and demonstration of sustainable management practices for Allegheny and northern hardwood forests; impacts of white-tailed deer herbivory
Massabesic, ME	Ecology and Management of Northern Forest Ecosystems	Demonstration of sustainable forest management practices
Penobscot, ME	Ecology and Management of Northern Forest Ecosystems	Long-term research and demonstration of sustainable silvicultural and management systems for northern conifer forests
Silas Little, NJ	[Managed by Rutgers University]	
Vinton Furnace, OH	Quantitative Methods for Modeling Forest Ecosystems	Long-term research and demonstration of sustainable management practices for oak-hickory forests
	North Central Research Station	
Argonne, WI	Ecology and Silviculture of the Northern Lakes States Forests	Management of second-growth northern hardwoods and balsam fir-aspen stands
Big Falls, MN	Ecology and Silviculture of the Northern Lakes States Forests	Management of black spruce swamp stands
Coulee, WI		Hydrology of forested and nonforested lands in the Driftless Area of southwestern Wisconsin
Cutfoot Sioux, MN	Ecology and Silviculture of the Northern Lakes States Forests	Management of red pine/jack pine stands
Kaskaskia, IL	Ecology and Management of Central Hardwood Ecosystems	Management of upland oak-hickory forests
Kawishiwi, MN	Ecology and Management of Riparian and Aquatic Ecosystems	Management of upland spruce stands in Laurentian Shield country
Lower Peninsula, MI	Stress Effects on Tree-Insect-Natural Enemy Interactions	Management of white pine and red pine plantations, and oak and aspen stands
Marcell, MN	Ecology and Management of Riparian and Aquatic Ecosystems	Basic and applied research in upland/peatland watersheds
McCormick, MI	Principles of Landscape Ecology for Managing Temperate Ecosystems	Landscape ecology
Paoli, IN	Ecology and Management of Central Hardwood Ecosystems	White and northern red oak planting
Pike Bay, MN	Ecology and Silviculture of the Northern Lakes States Forests	Management of aspen and mixed hardwoods
Sinkin, MO	Ecology and Management of Central Hardwood Ecosystems	Silviculture and ecology of oak-hickory ecosystems, with an emphasis on shortleaf pine and oak reproduction
Udel, MI	Stress Effects on Tree-Insect-Natural Enemy Interactions	Watershed management on deep sands
Upper Peninsula (Dukes), MI	Principles of Landscape Ecology for Managing Temperate Ecosystems	Management of mature northern hardwoods

last decade. For example, between 1985 and 1995, the total number of research scientists employed by the Forest Service declined nationally by 37 percent. The capacity to apply research results in forest management has been affected by similar staffing trends.

- Progress in forest ecology, landscape ecology, conservation biology, and genetics that is essential to understanding forest ecosystems is often dependent on long-term research.
- The National Science Foundation was instrumental in establishing a program on long-term ecological research in 1980. Seven out of 21 Long Term Ecological Research Program sites established across the country are located in the Northern United States, and 5 of these deal intensively with forested ecosystems (table 20). The Long Term Ecological Research Program research studies are carried out by a broad range of agencies, companies, and nonprofit organizations, and cover urban to rural and marine, aquatic, and terrestrial ecosystems.
- Research is needed to understand the tradeoffs inherent in environmental, social, and economic policies and the equitable distribution of costs for public benefits. An example application would be to evaluate public tax and zoning laws to identify what incentives and disincentives are in place to influence private forest landowner's decisions to develop or retain their land. Public benefits include water quality, air quality, biodiversity, and an aesthetic living environment.
- Several Forest Service research work units are examining methods to anticipate supply and demand for forest resources and to integrate environmental and social costs and benefits into public policies and landowner decisionmaking.
- Among all State and Federal agencies, the USDA Forest Service has the largest continuous research program aimed at recycling forest products. The Forest Service program is centered at the Forest Products Laboratory in Madison, Wisconsin. One of the greatest technical challenges to using recycled fiber in higher quality printing and writing papers is dealing with adhesive and plastic contaminants.
- There is national and international interest, yet uneven progress, in including environmental and social costs in national income accounts. Conventional economic accounting systems do not recognize the biophysical limits of what the environment can produce or what it can absorb in terms of disturbance or pollution. Likewise, conventional accounting systems tend to ignore or discount the value of future social benefits and costs.
- Technology has increased our ability to measure and model environmental changes. Advancements in remote sensing and geospatial modeling techniques have increased our predictive capabilities, although having the resources to conduct ground-truth investigations at an appropriate scale is often a critical limiting factor. Predictive modeling is also dependent on an increased understanding of the feedback mechanisms among ecological conditions, economic systems, and human behavior.
- Global change, including climate change, is a key national science initiative. The Executive Office of the President, through the National Science and Technology Council Committee on Environment and Natural Resources, developed the United States Global Change Research Program (USGCRP) in 1989 and formalized it in the Global Change

Table 20. **U.S. Long Term Ecological Research Sites**. Five of the seven U.S. Long Term Ecological Research Sites located within the Northern United States deal intensively with forested ecosystems. The sites represent terrestrial and aquatic ecosystems and urban to rural land use conditions (Source: U.S. Long Term Ecological Research Network).

LTER and Location	Principal biome or main communities	Research topics
Baltimore Ecosystem Study Baltimore, MD[1]	Eastern deciduous forest, suburban/agriculture fringe, urban parks, residential, and commercial patches, riparian and stream habitats	Patch dynamics of built, social, biological, and hydrological components of the Baltimore metropolitan area; feedbacks between social, economic, and ecological components of an urban ecosystem; effects on fluxes of nutrients, energy, and water in upland, stream, and coastal regions
Harvard Forest Petersham, MA[2]	*Eastern deciduous forest.* Hardwood-white pine-hemlock forest; spruce swamp forest; conifer plantations	Long-term climate change, disturbance history, and vegetation dynamics; community, population, and plant responses to human and natural disturbance; forest-atmosphere trace gas fluxes, organic matter and element cycling, fine root dynamics, and forest microbiology
Hubbard Brook West Thornton, NH[3]	*Eastern deciduous forest.* Northern hardwood forests, spruce-fir forests, streams and lakes	Vegetation structure and production; dynamics of detritus in terrestrial and aquatic systems; atmosphere-terrestrial-aquatic ecosystem linkages; heterotroph population dynamics; effects of human activities on ecosystems
Cedar Creek Minneapolis, MN[4]	*Eastern deciduous forest and tallgrass prairie.* Old fields, oak savanna and forest, conifer bogs; lakes; pine forest; wetlands	Successional dynamics; primary productivity and disturbance patterns; nutrient budgets and cycles; climatic variation and the wetland/upland boundary; plant-herbivore dynamics
North Temperate Lakes Boulder Lake and Madison, WI[5]	*Northern temperate lakes in urban, agricultural, and forested watersheds.* Lakes; ponds, streams; sphagnum-leatherleaf bogs; conifer swamps; mixed deciduous and coniferous forests	Physical, chemical, and biological limnology; hydrology and geochemistry; climate forcing; producer and consumer ecology; ecology of invasions; ecosystem variability; lakescape and landscape ecology

Institutional affiliation:

[1]Institute of Ecosystem Studies; USDA Forest Service; John Hopkins University; Yale University; University of Maryland; University of North Carolina; Parks and People Foundation; U.S. Geological Survey

[2]Harvard University, University of New Hampshire; University of Massachusetts; The Ecosystem Center, Marine Biological Laboratory

[3]Yale University; Cornell University; Syracuse University; Institute of Ecosystem Studies; USDA Forest Service, Northeastern Research Station

[4]University of Minnesota

[5]Center for Limnology, University of Wisconsin-Madison

Research Act of 1990. USGCRP research is organized to study global change; assess the consequences of such changes and the vulnerability of human and ecological systems to their potentially adverse impacts; develop the tools and capabilities to conduct integrated assessments; and synthesize and communicate this body of knowledge.

- The USGCRP draws together the results of the regional and sectoral analyses on the potential consequences of climate variability and change for the United States. Sectoral analyses are national in scope and consider the potential consequences on health, water, forests, agriculture, and coastal areas. In addition, regional analyses are conducted in 20 geographic regions throughout the country, six of which are in the Northern United States: Appalachian, Eastern Midwest, Great Lakes, Metro East, Mid-Atlantic, and New England.
- The Northern Global Change Research program operated by the USDA Forest Service looks at the effects of climate change on forests. The program is investigating processes in forest ecosystems that are sensitive to physical and chemical changes in the atmosphere and the implications for forest management.

Interrelationships Among Sustainability Criteria

The criteria and indicators are useful as a tool for comprehensively tracking trends in the components that are important to sustainability and evaluating them in relation to one another. It is essential to look at the big picture to determine how the environmental, social, and economic systems are interconnected. Taking this extra step helps identify pressing issues that have implications across the criteria and are critical to preserving the health of forest ecosystems for future generations. In the course of the assessment of forest sustainability for the Northern United States, several such issues have surfaced—the size of the forested land base, the degree of forest fragmentation, the age of the forest, the spread of exotic and invasive insects, diseases, and plants, and land ownership patterns.

The Size of the Forested Land Base

The increases in the forested land base over the last century are coming to end, and decreases are projected for the future. Genetic, species, and ecosystem diversity depend on the presence of forests and their associated plants and animals, as well as forest composition and distribution. The magnitude of forest land loss can have implications for the natural processes critical to ecosystem health. Social and economic benefits are affected by the amount of forest land available for harvesting wood and nonwood products, for recreation, and for general well-being. The size of the forested land base also influences environmental services related to clean air, water quality, and carbon storage. As less land is available to meet stable or increasing demands, competition among incompatible uses will increase, as will the need for public and institutional intervention in the provision of social goods and services.

The Degree of Forest Fragmentation

Forest fragmentation due to urban and suburban development is expected to have long-term negative effects across multiple criteria. The degree of impact varies across the region. The loss of large blocks of forested habitat for interior forest species and connectivity among remaining forest habitat raises concerns for biodiversity. The degree of fragmentation can affect the spread of insects and diseases, and reduce the quality of wildlife habitat for some species. Watershed hydrology is altered by the pattern and degree of development. Fragmentation affects the economic viability of wood harvest operations and, when associated with increased parcelization, often results in reduced public access for recreation. It also leads to changes in research and technical assistance needs and demands for services.

The Age of the Forest

The proportion of mature forests is increasing on a regional scale, with exceptions at subregional and landscape scales. The natural aging of forests provides opportunities to meet old growth and late successional wildlife management objectives, although at the landscape scale, management intervention may be necessary to maintain representative mid- and early successional communities. Large woody debris contributions to lakes, streams, and the forest floor may increase and improve habitat for some terrestrial and aquatic species. Forests of healthy mature trees have high economic and aesthetic value. As trees enter senescence they become more vulnerable to insects and disease, which may also affect their market value. Research, management, and public debate are likely to affect the desired balance among

age classes for the purposes of biodiversity, investment in forest industry, and community economic stability.

The Spread of Exotic and Invasive Insects, Diseases, and Plants

Exotic and invasive insects, diseases, and plants impact forest health and forest uses. The effects can be discerned at subregional, landscape, and local scales. Exotic and invasive species can alter the composition, structure, and processes of natural communities as well as wildlife habitat. Damaging agents can reduce both the resilience of forest ecosystems to environmental stresses and their productive capacity. Infestations can alter a forest's aesthetic qualities and its desirability for recreational purposes. Forest, recreation, wildlife, and nursery managers need to be alert to their roles in controlling and spreading insects and diseases. Management costs may increase as a result of needed control, and woodland owners and sawmill operators may see reduced values of harvested products.

Land Ownership Patterns

Landownership patterns in the Northern United States affect our ability to respond to forest health needs and management opportunities. Federal, State, county, municipal, industrial, and private lands each have important roles to play in achieving sustainability. They differ in their suitability for biodiversity conservation, wood production, recreation, and research, as well as offer varying levels of accessibility for management and recreation. Because the majority of forest land in the Northern United States is in private ownership, partnerships involving government and nongovernment organizations and individuals are not only desirable but necessary for the conservation and maintenance of forest ecosystems and the economic and social benefits derived from them. Laws, regulations, and voluntary approaches all have a place in efforts to achieve sustainability. In this environment, progress toward sustainability requires continuous public education and discourse. The availability of highly credible information is critical to informed discussion.

The issues identified deserve attention in an effort to develop effective programs and policies to achieve sustainability in the Northern United States. Changes in the size of the forested land base may lead to an increased need for public policy to address the availability of forest goods and services. Forest fragmentation can also lead to increased pressure on forest resources. The implementation of acceptable forest management practices are critical to meet biodiversity and economic stability. Controlling the spread of exotic and invasive pests is important to reducing their impact on the value of forest products. Overall, because so much forest land is in private ownership, partnerships between government, private organizations, and individuals are imperative to address sustainability within the region.

Appendix A. The Montreal Process Criteria and Indicators[1]

Criterion 1—Conservation of Biological Diversity

1.1 Ecosystem Diversity

1.1.a. Extent of area by forest type relative to total forest area

1.1.b. Extent of area by forest type and by age class or successional stage

1.1.c. Extent of area by forest type in protected area categories as defined by IUCN or other classification systems

1.1.d. Extent of areas by forest type in protected areas defined by age class or successional stage

1.1.e. Fragmentation of forest types

1.2 Species Diversity

1.2.a. The number of forest-dependent species

1.2.b. The status (threatened, rare, vulnerable, endangered, or extinct) of forest-dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment

1.3 Genetic Diversity

1.3.a. Number of forest-dependent species that occupy a small portion of their former range

1.3.b. Population levels of representative species from diverse habitats monitored across their range

Criterion 2—Maintenance of Productive Capacity of Forest Ecosystems

2.a. Area of forest land and net area of forest land available for timber production

2.b. Total growing stock of both merchantable and nonmerchantable tree species on forest land available for timber production

2.c. The area and growing stock of plantations of native and exotic species

2.d. Annual removal of wood products compared to the volume determined to be sustainable

2.e. Annual removal of nontimber forest products (e.g., fur bearers, berries, mushrooms, game), compared to the level determined to be sustainable

Criterion 3—Maintenance of Forest Ecosystem Health and Vitality

3.a. Area and percent of forest affected by processes or agents beyond the range of historic variation, (e.g., by insects, disease, competition from exotic species, fire, storm, land clearance, permanent flooding, salinization, and domestic animals)

3.b. Area and percent of forest land subjected to levels of specific air pollutants (e.g., sulfates, nitrate, ozone) or ultraviolet B that may cause negative impacts on the forest ecosystem

3.c. Area and percent of forest land with diminished biological components indicative of changes in fundamental ecological processes (e.g., soil, nutrient cycling, seed dispersion, pollination) and/or ecological continuity

Criterion 4—Conservation and Maintenance of Soil and Water Resources

4.a. Area and percent of forest land with significant soil erosion

4.b. Area and percent of forest land managed primarily for protective functions (e.g., watersheds, flood protection, avalanche protection, riparian zones)

4.c. Percent of stream kilometers in forested catchments in which stream flow and timing has significantly deviated from the historic range of variation

4.d. Area and percent of forest land with significantly diminished soil organic matter and/or changes in other soil chemical properties

4.e. Area and percent of forest land with significant compaction or change in soil physical properties resulting from human activities

[1]Formal title: Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests. (No priority or order is implied in the numeric listing of the criteria and indicators.)
Source: Montreal Process Working Group 1999.

4.f. Percent of water bodies in forest areas (e.g., stream kilometers, lake hectares) with significant variance of biological diversity from the historic range of variability

4.g. Percent of water bodies in forest areas (e.g., stream kilometers, lake hectares) with significant variation from the historic range of variability in pH, dissolved oxygen, levels of chemicals (electrical conductivity), sedimentation, or temperature change

4.h. Area and percent of forest land experiencing an accumulation of persistent toxic substances

Criterion 5—Maintenance of Forest Contribution to Global Carbon Cycles

5.a. Total forest ecosystem biomass and carbon pool, and if appropriate, by forest type, age class, and successional stages

5.b. Contribution of forest ecosystems to the total global carbon budget, including absorption and release of carbon (standing biomass, coarse woody debris, peat, and soil carbon)

5.c. Contribution of forest products to the global carbon budget

Criterion 6—Maintenance and Enhancement of Long-term Multiple Socio-economic Benefits to Meet the Needs of Societies

6.1 Production and consumption

6.1.a. Value and volume of wood and wood products production, including value added through downstream processing

6.1.b. Value and quantities of production of nonwood forest products

6.1.c. Supply and consumption of wood and wood products, including consumption per capita

6.1.d. Value of wood and nonwood products production as a percentage of GDP

6.1.e. Degree of recycling of forest products

6.1.f. Supply and consumption/use of nonwood products

6.2 Recreation and tourism

6.2.a. Area and percent of forest land managed for general recreation and tourism, in relation to the total area of forest land

6.2.b. Number and type of facilities available for general recreation and tourism, in relation to population and forest area

6.2.c. Number of visitor days attributed to recreation and tourism, in relation to population and forest area

6.3 Investment in the forest sector

6.3.a. Value of investment, including in forest growing, forest health and management, planted forests, wood processing, recreation and tourism

6.3.b. Level of expenditure on research and development, and education

6.3.c. Extension and use of new and improved technologies

6.3.d. Rates of return on investment

6.4 Cultural, social, and spiritual needs and values

6.4.a. Area and percent of forest land managed in relation to the total area of forest land to protect the range of cultural, social and spiritual needs and values

6.4.b. Nonconsumptive use forest values

6.5 Employment and community needs

6.5.a. Direct and indirect employment in the forest sector and forest sector employment as a proportion of total employment

6.5.b. Average wage rates and injury rates in major employment categories within the forest sector

6.5.c. Viability and adaptability to changing economic conditions, of forest-dependent communities, including indigenous communities

6.5.d. Area and percent of forest land used for subsistence purposes

Criterion 7—Legal, Institutional, and Economic Framework for Forest Conservation and Sustainable Management

7.1 Extent to which the *legal framework* (laws, regulations, guidelines) supports the conservation and sustainable management of forests, including the extent to which it:

- 7.1.a. Clarifies property rights, provides for appropriate land tenure arrangement, recognizes customary and traditional rights of indigenous people, and provides means of resolving property disputes by due process
- 7.1.b. Provides for periodic forest-related planning, assessment, and policy review that recognizes the range of forest values, including coordination with relevant sectors
- 7.1.c. Provides opportunities for public participation in public policy and decisionmaking related to forests and public access to information
- 7.1.d. Encourages best practice codes for forest management
- 7.1.e. Provides for the management of forests to conserve special environmental, cultural, social and/or scientific values

7.2 Extent to which the *institutional framework* supports the conservation and sustainable management of forests, including the capacity to:

- 7.2.a. Provide for public involvement activities and public education, awareness and extension programs, and make available forest-related information
- 7.2.b. Undertake and implement periodic forest-related planning, assessment, and policy review including cross-sectoral planning and coordination
- 7.2.c. Develop and maintain human resource skills across relevant disciplines
- 7.2.d. Develop and maintain efficient physical infrastructure to facilitate the supply of forest products and services and support forest management
- 7.2.e. Enforce laws, regulations, and guidelines

7.3 Extent to which the *economic framework* (economic policies and measures) supports the conservation and sustainable management of forests through:

- 7.3.a. Investment and taxation policies and a regulatory environment which recognize the long-term nature of investments and permit the flow of capital in and out of the forest sector in response to market signals, nonmarket economic valuations, and public policy decisions in order to meet long-term demands for forest products and services
- 7.3.b. Nondiscriminatory trade policies for forest products

7.4 Capacity to *measure and monitor* changes in the conservation and sustainable management of forests, including:

- 7.4.a. Availability and extent of up-to-date data, statistics and other information important to measuring or describing indicators associated with criteria 1–7
- 7.4.b. Scope, frequency, and statistical reliability of forest inventories, assessment, monitoring, and other relevant information
- 7.4.c. Compatibility with other countries in measuring, monitoring, and reporting on indicators

7.5 Capacity to conduct and apply *research and development* aimed at improving forest management and delivery of forest goods and services, including:

- 7.5.a. Development of scientific understanding of forest ecosystem characteristics and functions
- 7.5.b. Development of 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
- 7.5.c. New technologies and the capacity to assess the socio-economic consequences associated with the introduction of new technologies
- 7.5.d. Enhancement of ability to predict impacts of human intervention on forests
- 7.5.e. Ability to predict impacts on forests of possible climate change

Appendix B. Federal Threatened and Endangered Species in the Northern United States

Common name	Scientific name	Status[1]
Mammals		
Delmarva peninsula fox squirrel	*Sciurus niger cinereus*	E
Eastern cougar	*Felis concolor couguar*	E
Gray bat	*Myotis grisescens*	E
Gray wolf	*Canis lupus*	E & T
Indiana bat	*Myotis sodalis*	E
Ozark big-eared bat	*Plecotus townsendii ingens*	E
Virginia big-eared bat	*Plecotus townsendii virginianus*	E
Virginia northern flying squirrel	*Glaucomys sabrinus fuscus*	E
Birds		
Bald eagle	*Haliaeetus leucocephalus*	T
Kirtland's warbler	*Dendroica kirtlandii*	E
Least tern	*Sterna antillarum*	E
Piping plover	*Charadrius melodus*	E & T
Roseate tern	*Sterna dougallii (dougallii)*	E
Reptiles		
Bog turtle	*Clemmys muhlenbergii*	T
Copperbelly water snake	*Nerodia erythrogaster neglecta*	T
Green sea turtle[2]	*Chelonia mydas*	T
Hawksbill sea turtle[2]	*Eretmochelys imbricata*	E
Kemp's (=Atlantic) ridley sea turtle[2]	*Lepidochelys kempii*	E
Lake Erie water snake	*Nerodia sipedon insularum*	T
Leatherback sea turtle[2]	*Dermochelys coriacea*	E
Loggerhead sea turtle[2]	*Caretta caretta*	T
Plymouth redbelly turtle	*Pseudemys rubriventris bangsi*	E
Amphibians		
Cheat Mountain salamander	*Plethodon nettingi*	T
Fishes		
Maryland darter	*Etheostoma sellare*	E
Neosho madtom	*Noturus placidus*	T
Niangua darter	*Etheostoma nianguae*	T
Ozark cavefish	*Amblyopsis rosae*	T
Pallid sturgeon	*Scaphirhynchus albus*	E
Scioto madtom	*Noturus trautmani*	E
Shortnose sturgeon	*Acipenser brevirostrum*	E
Topeka shiner	*Notropis topeka*	E
Crustaceans		
Hays Springs amphipod	*Stygobromus hayi*	E
Illinois cave amphipod	*Gammarus acherondytes*	E
Clams		
Clubshell	*Pleurobema clava*	E
Cracking pearlymussel	*Hemistena (Lastena) lata*	E
Curtis' pearlymussel	*Epioblasma florentina curtisi*	E
Dwarf wedgemussel	*Alasmidonta heterodon*	E
Fanshell	*Cyprogenia stegaria (=C. Irrorata)*	E
Fat pocketbook	*Potamilus capax*	E
Higgins' eye pearlymussel	*Lampsilis higginsi*	E

[1]E = endangered
T = threatened

[2]Denotes coastal species. (The six oceanic species are not included in this list.)
Source: McLellan 1998, U.S. Fish and Wildlife Service 1999.

Appendix B

Common name	Scientific name	Status
Clams (continued)		
James River spinymussel	*Pleurobema collina*	E
Northern riffleshell	*Epioblasma torulosa rangiana*	E
Orange-foot pearlymussel	*Plethobasus cooperianus*	E
Pink mucket pearlymussel	*Lampsilis abrupta*	E
Purple cat's paw pearlymussel	*Epioblasma (=dysnomia) obliquata obliquata*	E
Ring pink mussel	*Obovaria retusa*	E
Rough pigtoe	*Pleurobema plenum*	E
Tubercled-blossom pearlymussel	*Epioblasma (=Dysnomia) torulosa torulosa*	E
White cat's paw pearlymussel	*Epioblasma obliquata perobliqua*	E
White wartyback pearlymussel	*Plethobasus cicatricosus*	E
Winged mapleleaf mussel	*Quadrula fragosa fragosa*	E
Snails		
Chittenango ovate amber snail	*Succinea chittenangoensis*	T
Flat-spired three-toothed snail	*Triodopsis platysayoides*	T
Iowa Pleistocene snail	*Discus macclintocki*	E
Insects		
American burying beetle (=giant carrion)	*Nicrophorus americanus*	E
Hine's (=Ohio) emerald dragonfly	*Somatochlora hineana*	E
Hungerford's crawling water beetle	*Brychius hungerfordi*	E
Karner blue butterfly	*Lycaeides melissa samuelis*	E
Mitchell's satyr butterfly	*Neonympha mitchellii mitchellii*	E
Northeastern beach tiger beetle	*Cicindela dorsalis dorsalis*	T
Puritan tiger beetle	*Cicindela puritana*	E
Plants		
American chaffseed	*Schwalbea americana*	E
American hart's-tongue fern	*Asplenium scolopendrium* var. *americanum*	T
Canby's dropwort	*Oxypolis canbyi*	E
Decurrent false aster	*Boltonia decurrens*	T
Dwarf lake iris	*Iris lacustris*	T
Eastern prairie fringed orchid	*Platanthera leucophaea*	T
Fassett's locoweed	*Oxytropis campestris* var. *chartacea*	T
Furbish's lousewort	*Pedicularis furbishiae*	E
Geocarpon (no common name)	*Geocarpon minimum*	T
Harperella	*Ptilimnium nodosum (=fluviatile)*	E
Houghton's goldenrod	*Solidago houghtonii*	T
Jesup's milk-vetch	*Astragalus robbinsii* var. *Jesupi*	E
Knieskern's beaked-rush	*Rhynchospora knieskernii*	T
Lakeside daisy	*Hymenoxys herbacea*	T
Leafy prairie-clover	*Dalea foliosa*	E
Leedy's roseroot	*Sedum integrifolium* var. *leedyi*	T
Mead's milkweed	*Asclepias meadii*	T
Michigan monkey-flower	*Mimulus glabratus* var. *michiganensis*	E
Minnesota dwarf trout lily	*Erythronium propullans*	E
Missouri bladderpod	*Lesquerella filiformis*	E
Northeastern (=barbed bristle) bulrush	*Scirpus ancistrochaetus*	E
Northern wild monkshood	*Aconitum noveboracense*	T
Pitcher's thistle	*Cirsium pitcheri*	T
Pondberry	*Lindera melissifolia*	E
Prairie bush-clover	*Lespedeza leptostachya*	T
Price's potato-bean	*Apios priceana*	T
Robbins' cinquefoil	*Potentilla robbinsiana*	E
Running buffalo clover	*Trifolium stoloniferum*	E
Sandplain gerardia	*Agalinis acuta*	E

Common name	Scientific name	Status
Plants (continued)		
Seabeach amaranth	*Amaranthus pumilus*	T
Sensitive joint-vetch	*Aeschynomene virginica*	T
Shale barren rock-cress	*Arabis serotina*	E
Small whorled pogonia	*Isotria medeoloides*	T
Smooth coneflower	*Echinacea laevigata*	E
Swamp pink	*Helonias bullata*	T
Virginia sneezeweed	*Helenium virginicum*	T
Virginia spiraea	*Spiraea virginiana*	T
Western prairie fringed orchid	*Platanthera praeclara*	T

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