Forest Sustainability Assessment for the Northern United States

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Northeastern Area
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Constance A. Carpenter

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Executive Summary

The *Forest Sustainability Assessment for the Northern United States* provides a snapshot of today's forests and a baseline for tracking future trends. This comprehensive assessment of forest sustainability is 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 affect 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-1900s, 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. Exotic species 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 Contributions 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 is an important source of income in some locales and is often strongly interwoven into the social and cultural traditions of communities.

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 Brundtland Commission Report to the World Commission on Environment and Development set off a firestorm of discussion regarding the concept of sustainability when it defined sustainable development as "development to meet the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987, p. 43). Since then, the terms forest sustainability, sustainable forestry, sustainable forest management, and sustainable development have become common catchphrases among natural resource policymakers. Most natural resource organizations—public, private nonprofit, and private industry groups—today have developed working definitions of one or more of these terms, which, collectively, reveal the core tenets of sustainability.

Sustainability

- The continued existence and use of forests to meet human physical, economic, and social needs.
- The desire to preserve the health of forest ecosystems in perpetuity.
- The ethical choice of preserving options for future generations while meeting the needs of the present.

Concerns over forest sustainability are not only the purview of the resource professional. Most citizens expect the Nation's natural resources to be used wisely and expect an accounting of those uses, resulting conditions, and possible future effects. Public agencies have long reported on the time and money used in natural resource management. The question is how to determine whether forest land and resource uses are sustainable.

The use of criteria and indicators of sustainability is a means to identify important land use and management trends that may have an effect on sustainability. **Criteria** are goals or categories that reflect broad public values and recognized scientific principles. They provide the big picture of what people want to see in forests and as objectives of forest management. Seven criteria of sustainability have been endorsed by the United States as part of an international commitment to forest sustainability called the Santiago Agreement.

Indicators are the measures used to track forest conditions and the environmental, social, and economic changes that affect society's ability to meet its goals. There are 67 indicators associated with the 7 international criteria of sustainability. They are collectively referred to as the Montreal Process Criteria and Indicators.

History of the Development of the Montreal Process Criteria and Indicators and Their Use in the United States

The Earth Summit and Statement of Forest Principles: In 1992, the United Nations sponsored a Conference on Environment and Development in Rio de Janeiro, Brazil, commonly referred to as the Earth Summit. At the summit over 144 nations recognized the importance of sustainably managing all types of forests in order to meet the needs of present and future generations by adopting a nonbinding Statement of Forest Principles.

The Montreal Process Criteria and Indicators: Following the Earth Summit, the United Nations Conference on Security and Cooperation in Europe sponsored an international seminar in Montreal, Canada, on Sustainable Development of Boreal and Temperate Forests. This forum focused on how to measure and track progress in sustainability. These discussions provided the basis for subsequent regional and international initiatives to develop criteria, which reflect widely held public values, and indicators, which provide a means of measuring forest conditions and tracking changes in environmental, social, and economic conditions. The United States joined the Montreal Process Working Group, which recommended the 7 criteria and 67 indicators now referred to as the Montreal Process Criteria and Indicators.

The Santiago Declaration: In 1995, the United States signed the Santiago Declaration, a statement of political commitment by nations to use the Montreal Process Criteria and Indicators to track progress in sustainability. Other signatories to this nonbinding declaration include Argentina, Canada, Chile, China, Japan, the Republic of Korea, Mexico, New Zealand, the Russian Federation, and Uruguay. Collectively, these countries contain 90 percent of the world's temperate and boreal forests, 60 percent of all forests on the globe. They also account for 35 percent of the world's population and 45 percent of related world trade.

The United States First Approximation Report: The United States issued its first national report on June 6, 1997. *The First Approximation Report for Sustainable Forest Management: Report of the United States on the Criteria and Indicators for the Sustainable Management of Temperate and Boreal Forests* laid the foundation for an ongoing process to assess forest management and monitoring capability across the country. A consolidated report from all Montreal Process Working Group countries was presented to the 11th World Forestry Congress in Antalya, Turkey, in October 1997.

The U.S. Roundtable on Sustainable Forests: A National Roundtable on Sustainable Forests has been convened by the chief of the USDA Forest Service to advance dialogue on sustainable forest management in the United States and to facilitate national collaboration on a second United States report based on the Montreal Process Criteria and Indicators. The roundtable process includes State Foresters, environmental groups, Federal agencies, private forest owners, forest products companies, State and local elected officials, tribal organizations, professional forester organizations, labor organizations, and academic institutions. Many of these groups are already beginning to collect and contribute data to the criteria and indicators effort and to help further the dialogue about sustainable forest management in the United States.

Report Objectives

This report uses the sustainability criteria as a framework for identifying forest sustainability trends in the Northern United States—an area encompassing 20 States and the District of Columbia (figure 1). The information in this report provides a regional perspective that State and local governments can link to in their own sustainability assessment and planning activities. It is designed to raise awareness regarding the state of the forest resource and its management. By providing a public source of information, it is thought to be a useful tool for encouraging discussion among forest stakeholders, forest managers, and policymakers.

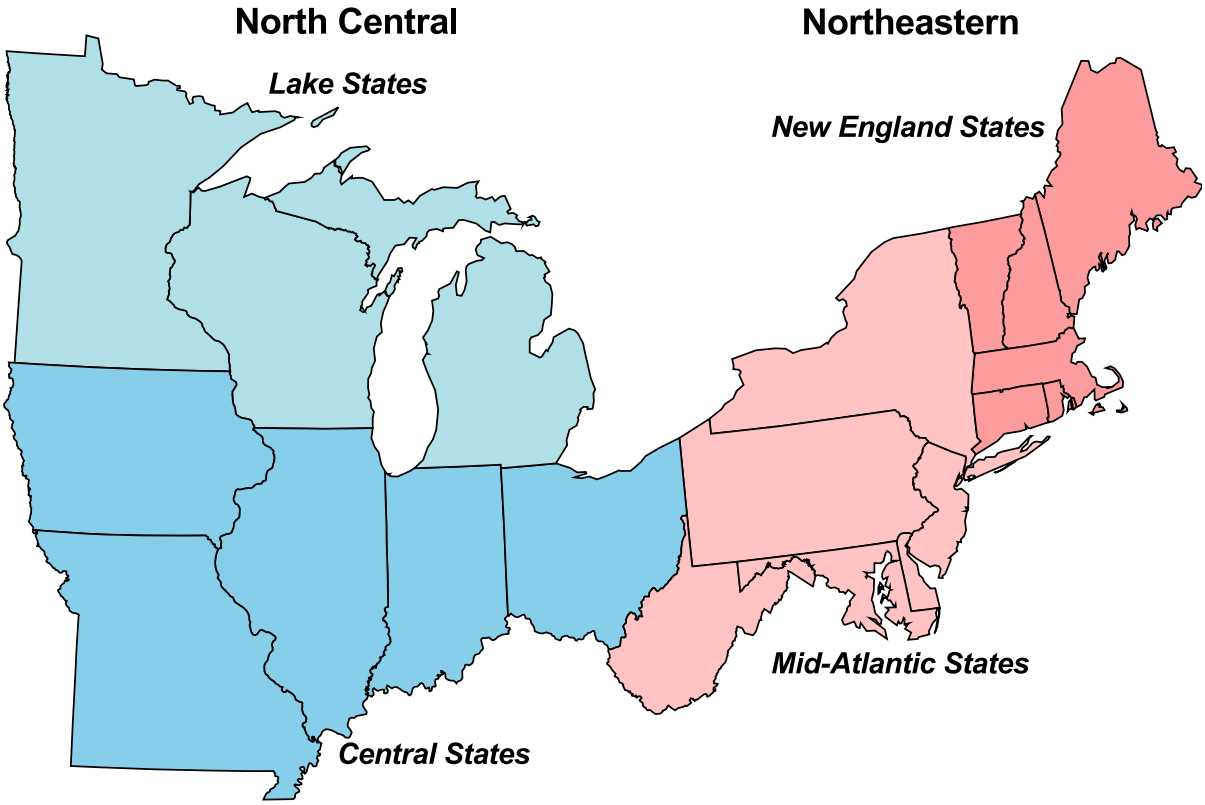

Figure 1. **The Northern United States.** The 20 States covered in this report may be subdivided into the multistate units shown for reporting purposes.

How To Use This Report

This report is organized according to the 7 sustainability criteria and 67 associated indicators listed on pages 10 through 14. Each chapter introduces scientific concepts associated with one of the seven criteria and other factors considered in addressing the indicators. All sustainability indicators are interconnected. The final chapter presents five significant trends and examples of potentials impacts that cut across all of the criteria.

The indicators are addressed to the extent practicable by synthesizing readily available information. The report includes an extensive reference list and detailed appendixes. Both quantitative and qualitative information were used to provide a snapshot of conditions to serve as a baseline for future work. No new inventory or monitoring activities were initiated to complete this report; hence, it serves to highlight where information gaps exist.

A summary and conclusions section is included for each criterion. The report is intended to identify trends in forest resource conditions and uses. It does not include program or management recommendations, although it does describe the legal, institutional, and economic framework in place to promote sustainability. A companion document, *Sustainability Assessment Highlights for the Northern United States* (Carpenter and others 2003), presents the most salient information from this report in an abbreviated format.

The Montreal Process Criteria and Indicators[1]

Criterion 1—Conservation of Biological Diversity

Ecosystem Diversity

1. Extent of area by forest type relative to total forest area
2. Extent of area by forest type and by age class or successional stage
3. Extent of area by forest type in protected area categories as defined by International Union for the Conservation of Nature or other classification systems
4. Extent of areas by forest type in protected areas defined by age class or successional stage
5. Fragmentation of forest types

Species Diversity

6. The number of forest-dependent species
7. 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

Genetic Diversity

8. Number of forest-dependent species that occupy a small portion of their former range
9. Population levels of representative species from diverse habitats monitored across their range

Criterion 2—Maintenance of Productive Capacity of Forest Ecosystems

10. Area of forest land and net area of forest land available for timber production
11. Total growing stock of both merchantable and nonmerchantable tree species on forest land available for timber production
12. The area and growing stock of plantations of native and exotic species
13. Annual removal of wood products compared to the volume determined to be sustainable

[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.

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

Criterion 3—Maintenance of Forest Ecosystem Health and Vitality

15. 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)
16. 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
17. 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

18. Area and percent of forest land with significant soil erosion
19. Area and percent of forest land managed primarily for protective functions (e.g., watersheds, flood protection, avalanche protection, riparian zones)
20. Percent of stream kilometers in forested catchments in which stream flow and timing has significantly deviated from the historic range of variation
21. Area and percent of forest land with significantly diminished soil organic matter and/or changes in other soil chemical properties
22. Area and percent of forest land with significant compaction or change in soil physical properties resulting from human activities
23. 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
24. 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
25. Area and percent of forest land experiencing an accumulation of persistent toxic substances

Criterion 5—Maintenance of Forest Contributions to Global Carbon Cycles

26. Total forest ecosystem biomass and carbon pool, and if appropriate, by forest type, age class, and successional stages
27. 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)
28. 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

Production and consumption

29. Value and volume of wood and wood products production, including value added through downstream processing
30. Value and quantities of production of nonwood forest products
31. Supply and consumption of wood and wood products, including consumption per capita
32. Value of wood and nonwood products production as a percentage of gross domestic product
33. Degree of recycling of forest products
34. Supply and consumption/use of nonwood products

Recreation and tourism

35. Area and percent of forest land managed for general recreation and tourism, in relation to the total area of forest land
36. Number and type of facilities available for general recreation and tourism, in relation to population and forest area
37. Number of visitor days attributed to recreation and tourism, in relation to population and forest area

Investment in the forest sector

38. Value of investment, including in forest growing, forest health and management, planted forests, wood processing, recreation and tourism
39. Level of expenditure on research and development, and education
40. Extension and use of new and improved technologies
41. Rates of return on investment

Cultural, social, and spiritual needs and values

42. 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
43. Nonconsumptive use forest values

Employment and community needs

44. Direct and indirect employment in the forest sector and forest sector employment as a proportion of total employment
45. Average wage rates and injury rates in major employment categories within the forest sector
46. Viability and adaptability to changing economic conditions of forest-dependent communities, including indigenous communities
47. Area and percent of forest land used for subsistence purposes

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

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

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

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

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

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

58. 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
59. Nondiscriminatory trade policies for forest products

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

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

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

63. Development of scientific understanding of forest ecosystem characteristics and functions
64. 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
65. New technologies and the capacity to assess the socio-economic consequences associated with the introduction of new technologies
66. Enhancement of ability to predict impacts of human intervention on forests
67. Ability to predict impacts on forests of possible climate change

Criterion 1

Conservation of Biological Diversity

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Criterion 1. Conservation of Biological Diversity

Constance Carpenter,[1] Thomas Schmidt,[2] Toni McLellan,[1] Richard Cooksey,[3] and Karen Felton[4]

Biological diversity or **biodiversity** is the variety of life forms and processes that support them (Keystone Center 1991). The lands and waters of the Northern United States are home to a wide range of plants, animals, and microorganisms that interact to form natural communities and ecosystems. Keeping these natural systems resilient and functioning helps to maintain the benefits derived from them. The diversity of life is a basic property of nature that sustains ecosystems and human populations by providing a vast array of food, wood fiber, health, recreation, aesthetic, and other benefits.

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 1.1). **Ecosystem diversity** generally refers to the variety of physical environments and biotic communities over a landscape. Maintaining **species diversity** means maintaining groups of interbreeding natural populations. **Genetic diversity** comprises the variation among genes of plants, animals, and microorganisms that inhabit the earth and affect the adaptability of organisms to their environment. Biological diversity can be described at local to global scales and over timeframes that range to millennia.

Genetic diversity
The variation in genetic composition of individuals within and among species (e.g., variation within 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).

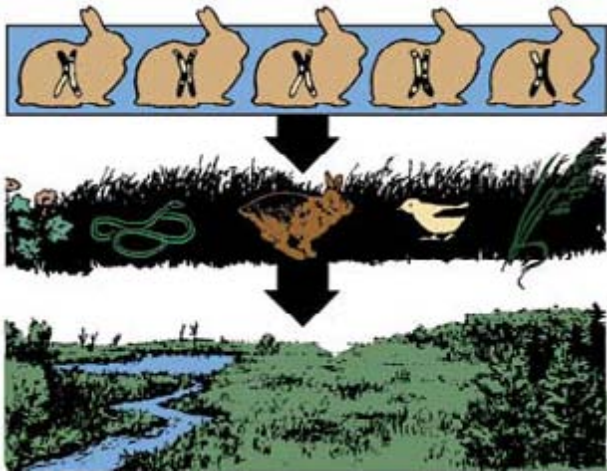


Figure 1.1. **Types of biological diversity**. There are three widely recognized types of biological diversity: genetic diversity, species diversity, and ecosystem diversity, which includes community diversity (Source: reproduced from Temple 1991 with author's permission).

[1]USDA Forest Service, Northeastern Area State and Private Forestry, Durham, NH
[2]USDA Forest Service, North Central Research Station, St. Paul, MN
[3]USDA Forest Service, Washington, DC
[4]USDA Forest Service, Northeastern Area State and Private Forestry, Morgantown, WV

Ecosystems

Ecosystems are complex interacting systems of organisms and their environment. They are distinguished by their composition, structure, and function.

- **Composition** is the fundamental components of a system. Composition includes the genes, species, and physical elements that make up an ecosystem—or some combination of the same—that functions as an organic whole.
- **Structure** is the arrangement of components relative to each other in time and space. Structure includes the size, shape, and distribution of species, habitats, and communities across the landscape, and patterns of successional change.
- **Function** is the processes through which components of ecosystems interact and adapt to change. Functions include ecological interactions such as growth, succession, evolution, pollination, predation, and herbivory; nutrient, water, and energy cycling; and the varying cycles and intensities of natural disturbances such as fire, ice, and windthrow.

Ecological units provide working definitions of ecosystems. Ecological units are geographic units based on the composition, structure, and functional elements of the ecosystem at the scale of their intended use. In general, the broader the scale, the more elements of biological diversity expected within a unit. Ecological units are useful for planning and assessments at local, State, regional, and national scales. The USDA Forest Service uses the **National Hierarchical Framework of Ecological Units** for these purposes (table 1.1). The **province** is one level of the national hierarchy that contains a unique mosaic of physical features, vegetation, and community structure. Provinces span multiple States. The map in figure 1.2 displays nine provinces referenced in this assessment. It includes a proposed boundary to divide Province 222 into two provinces. Provinces provide an ecologic context for interpreting the resource inventories used in this report.

Table 1.1. **The National Hierarchical Framework of Ecological Units**. This framework consists of a four-level hierarchy for planning and assessment tied to an eight-level ecological classification system. It is used to stratify the earth into progressively smaller areas of increasingly uniform ecological potential. Small ecological units are nested within larger units and provide a means of aggregating and disaggregating associated information for analysis (Cleland and others 1997).

Application scale	Purpose of use	Ecological units
Global, continental, regional levels	Long-term, broad-scale planning and assessment. Broad applicability for modeling and sampling.	Domain Division Province
Multi-forest, State or multistate projects, river basin projects	Strategic and multi-agency analysis and assessment. Data aggregation. Generating and testing research hypotheses. Technology transfer/data extrapolation.	Section Subsection
Area-wide, forest, State, multi-county, watershed, riparian or wildlife corridors	Multiple resource assessment and analysis. Tactical and long-term operational planning. Data aggregation. Research and monitoring design.	Landtype association Ecological land type Ecological land type phase

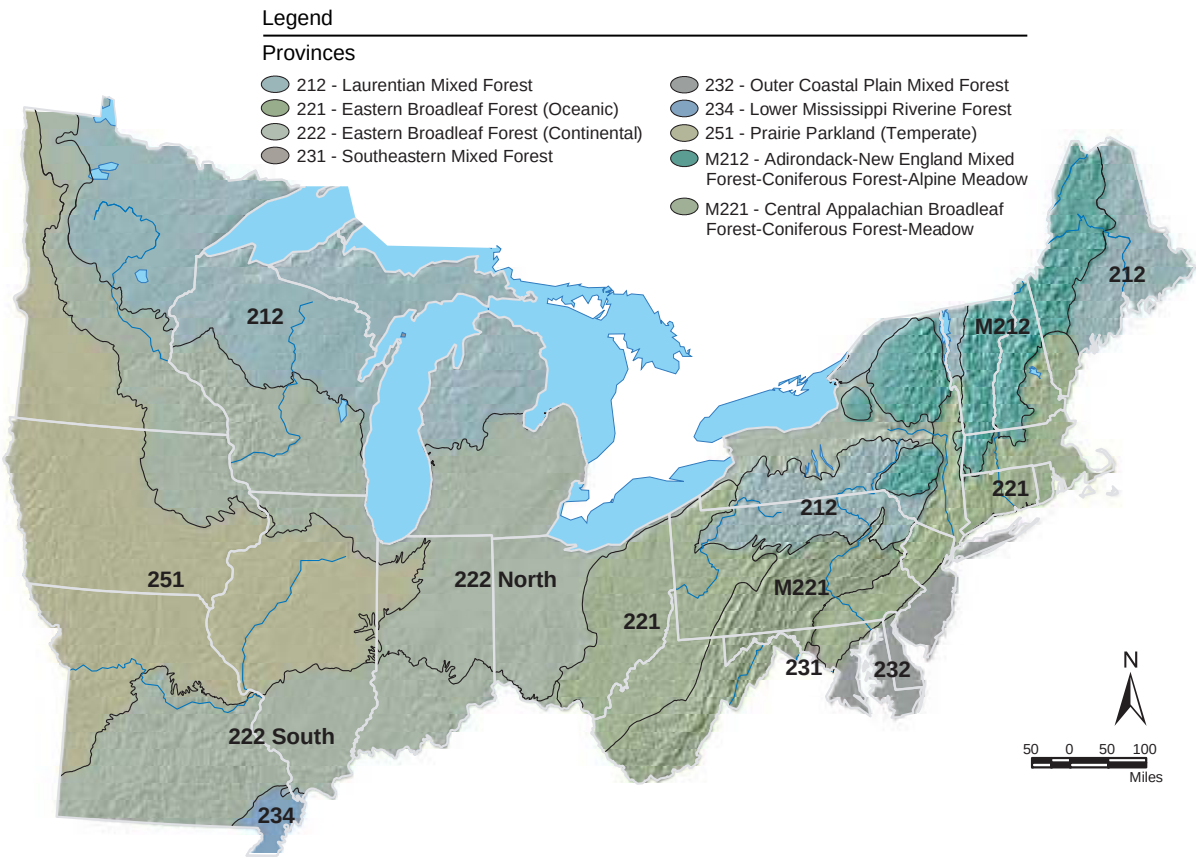


Figure 1.2. **Ecological units of the Northern United States**. Provinces on this map were developed by the USDA Forest Service by using the National Hierarchical Framework of Ecological Units (see table 1.1). Ecological units reflect the inherent biological capability of an ecosystem; therefore, they 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).

Land Use History

Roughly 41 percent (169 million acres) of the 413 million acres of land in the Northern United States is forested (USDA Forest Service1999). These **forest lands** include all land that is at least 10 percent stocked by forest trees of any size and land that formerly had trees and will be naturally or artificially regenerated (Hansen and others 1992). The patterns of land cover and use are an important factor for biodiversity conservation. For example, contiguous forest is an important habitat component for some wildlife species whereas other species thrive where more open land is available (Cody 1985).

In 1630, shortly after European settlement began, forests covered roughly 73 percent of the Northern United States (Smith and others 2001), whereas at the beginning of the 20th century, forest cover had dropped to as little as 34 percent. Northern U.S. forest acreage has been increasing steadily on a regional basis since the turn of the century, but the amount of forest is not expected to return to presettlement levels since some historically forested land will continue to be used for farming and development.

Differences in natural potential can be tracked conveniently by province and related to the history of the region. Forest acreage is not distributed evenly across the region (figure 1.3, appendix 1–A). The relative abundance of forested and nonforested land varies within and among provinces owing to the combined influence of natural history and the legacy of human activities (Irland 1998, McNab and Avers 1994, Smith and others 2001).

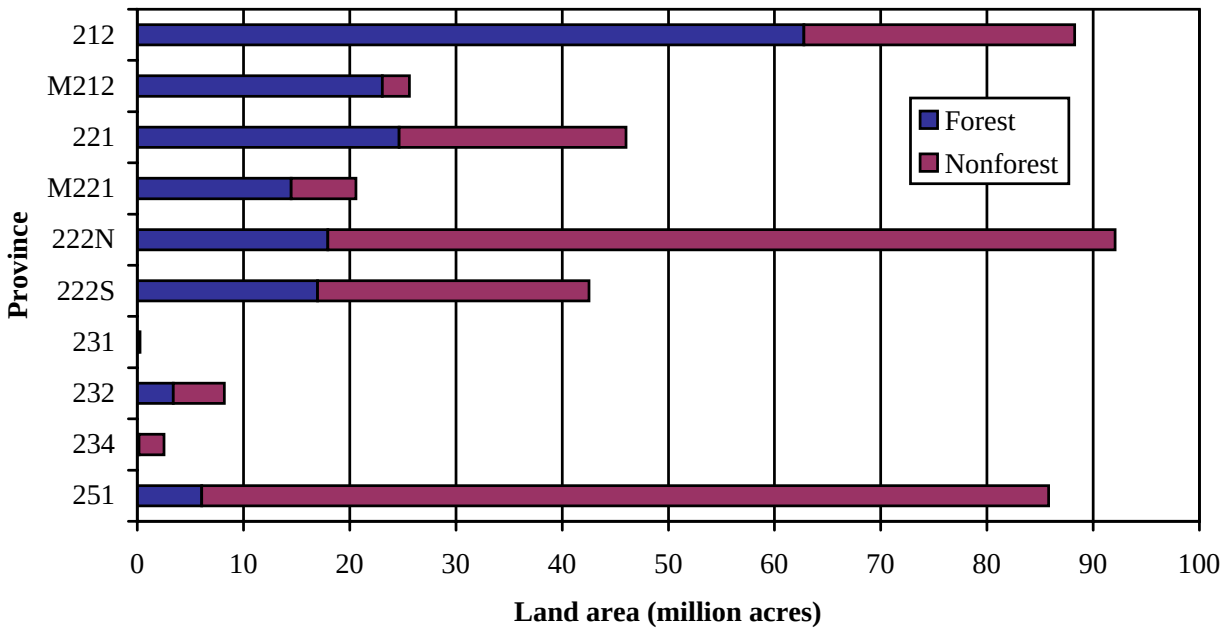


Figure 1.3. **The amount of forested and nonforested land[1] in each province[2] of the Northern United States** (USDA Forest Service 1999b[3]).

[1]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. Does not include 2,594,600 acres of Adirondack and Catskill preserves (NY).
[2]Provinces are displayed in figure 1.2.
[3]Inventory follows methods in Hansen and others (1992).

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 were over 90 percent forest prior to European settlement. They have the highest percentages of forest cover across the Northern United States today. The forest resources were heavily timbered during European settlement. Branches and residue left on the forest floor following initial harvest provided kindling for historic slash fires that affected whole landscapes and watersheds. Much of the forest that was cleared for crops and pasturage was quite marginal and reverted back to forest after farm abandonment in the early 20th century. The historical forest lands that have remained in farming are located predominantly in valleys, glacial lake plains, and hilltops. These provinces continue to be less populated than the other provinces in the Northern United States owing to the cold climate, shorter growing seasons, and often rugged topography. Together they account for over half of the forest land found in the northern United States today (Irland 1998, McNab and Avers 1994, Minnesota 1974, Smith and others 2001, Wisconsin 1976).

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. All but the most unproductive and inaccessible forest land was converted for farm use while the forest resources were heavily exploited for fuelwood, charcoal, local construction, industry, and export. Most reclaimed forest land today sports second- or third-growth forest. Province 221 includes southern New England and most of the Piedmont in the northeastern United States. It is referred to as the farm and forest region as it is 51 percent forested. Province 232 is only 41 percent forested. 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 whereas 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 land cleared for farming remains in agricultural use today, although marginal, often heavily eroded cropland has reverted to forest cover or was reclaimed as forest land 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, although upland forests and savannas 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 critical for maintaining plant and animal diversity (McNab and Avers 1994, Smith and others 2001).

Indicator 1. Extent of area by forest type relative to total forest area

The amount, type, and distribution of forest land at global to local scales has important implications for humans and animal and plant species. Particular forest types may have the physical or structural features necessary to a species' survival or may create environmental conditions that favor different associates. The Society of American Foresters forest cover type classification (Eyre 1980) as adapted by the USDA Forest Service Forest Inventory and Analysis Program (FIA) (Hansen and others 1992) and the U.S. National Vegetation Classification System (Anderson and others 1998, Grossman and others 1998) have been used in this report.

Forest Cover Type Inventory

Forest cover types are groupings of trees distinguished from one another by the relative stocking of tree species as tallied on inventory plots. Each cover type is named after the predominant tree species. Sixty-four forest cover types are inventoried by the FIA Program in the Northern United States (table 1.2). These cover types have been combined 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 1.4).

Table 1.2. **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). See appendix 1–B for a listing of the scientific name of each species.

Aspen-Birch Group	**Oak-Hickory Group**
Aspen	Post/blackjack oak
Paper birch	Chestnut oak
Gray birch	White oak/red oak/hickory
Balsam poplar	White oak
	Northern red oak
Elm-Ash-Red Maple Group	Yellow-poplar/white oak/northern red oak
Black ash/American elm/red maple	Sassafras/persimmon
River birch/sycamore	Sweetgum/yellow-poplar
Cottonwood	Scarlet oak
Willow	Yellow-poplar
Sycamore/pecan/American elm	Black walnut
Sugarberry/hackberry/American elm/green ash	Black locust
Silver maple/American elm	Chestnut oak/black oak/scarlet oak
Red maple/lowlands	Red maple/oak
Cottonwood/willow	Mixed upland hardwoods
Loblolly-Shortleaf Pine Group	**Oak-Pine Group**
Loblolly pine	White pine/northern red oak/white ash
Shortleaf pine	Eastern redcedar/hardwood
Virginia pine	Shortleaf pine/oak
Table-mountain pine	Virginia pine/southern red oak
Pond pine	Loblolly pine/hardwood
Pitch pine	Other oak/pine
Maple-Beech-Birch Group	**Spruce-Fir Group**
Sugar maple/beech/yellow birch	Balsam fir
Black cherry	White spruce
Cherry/ash/yellow-poplar	Red spruce
Hard maple/basswood	Red spruce/balsam fir
Elm/ash/locust	Black spruce
Red maple/uplands	Tamarack (eastern larch)
	Northern white cedar
Oak-Gum-Cypress Group	
Swamp chestnut oak/cherrybark oak	**White-Red-Jack Pine Group**
Sweetgum/Nuttall oak/willow oak	Jack pine
Overcup oak/water hickory	Red pine
Atlantic white cedar	White pine
Baldcypress/water tupelo	White pine/hemlock
Sweetbay/swamp tupelo/red maple	Hemlock

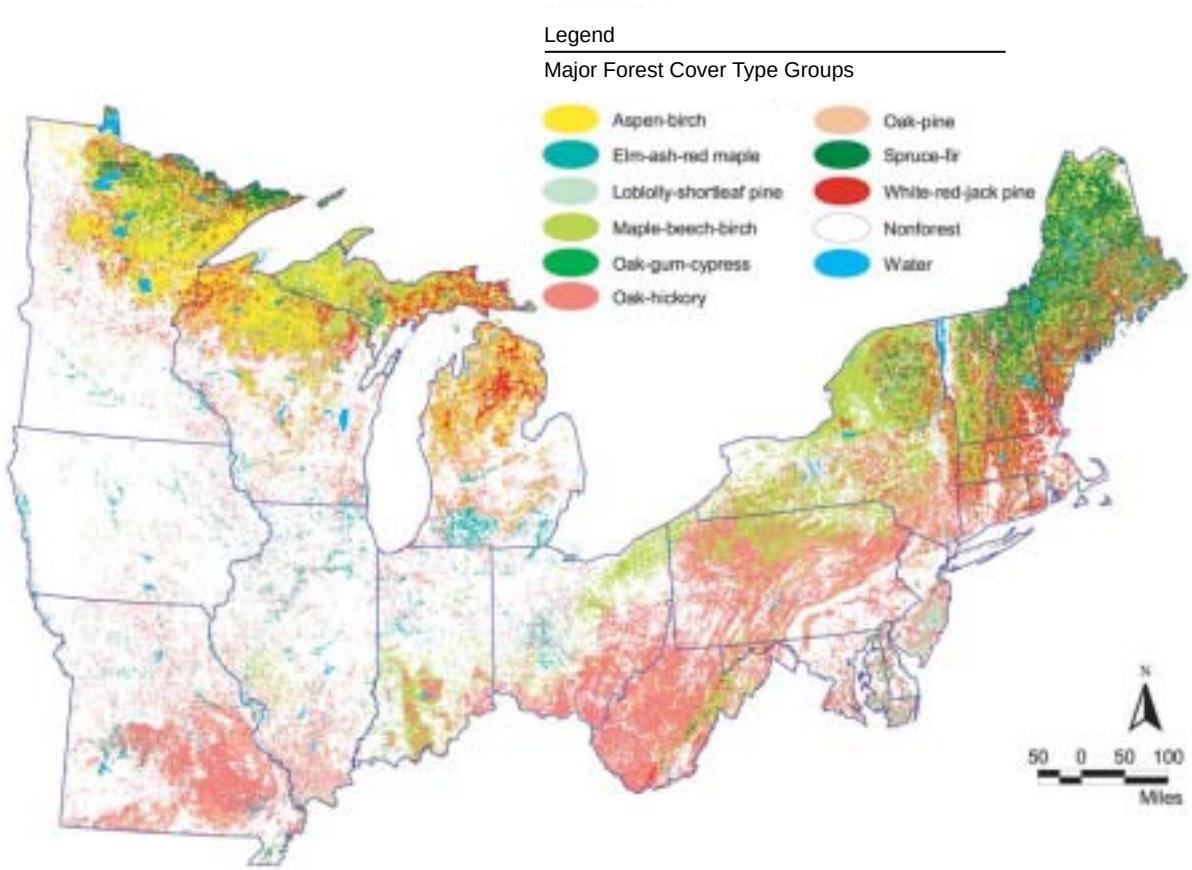


Figure 1.4. **Forest cover type groups in the Northern United States** (Source: developed by the USDA Forest Service Forest Inventory and Analysis Group by using AVHRR [Advanced Very High Resolution Radiometer] data).

The most extensive forest cover type groups are oak-hickory and maple-beech-birch (table 1.3). They each occupy over 50 million acres of forest land, and together they occupy more than 60 percent of the forested land area in the Northern United States. They occur in every ecological province but in different proportions, a critical consideration in biodiversity conservation and management. The amount of oak-hickory acreages ranges from a low of 4 percent of the forest land in Province M212 to 89 percent of the forest land in Province 231. Only a small percentage of the forest land in the Outer Coastal Plain Province 232 is in the Northern United States. However, the greatest diversity of oak types appears to be in this province, where 68 percent of the forest land is in an oak-pine, oak-hickory, or oak-gum-cypress type groups. The amount of maple-beech-birch type ranges from a low of 2 percent of the forest land in Province 232 to a high of 58 percent of the forest land in Province M212.

Province 212 has the most forest land (> 62 million acres). It contains the majority of the aspen-birch (80 percent), spruce-fir (74 percent), and white-red-jack pine (52 percent) found in the region and a substantial part of the maple-beech-birch (40 percent). An estimated 98 percent of the spruce-fir in the region occurs in Provinces 212 and M212 combined.

Table 1.3. **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, spruce-fir, and aspen-birch (USDA Forest Service 1999b[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[4]	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).
[4]Timberland less than 10 percent stocked with all live trees.

Knowledge of the range and relative dominance of forest types over the course of history provides a desirable beginning point for ecosystem diversity assessments at broad scales. The period of European settlement is a turning point in land use and management activity that provides a useful reference point for comparison. Although it appears that presettlement forest cover types in the Northern United States were similar to those that occur today, there is limited information available to compare total floristic composition within these types (Delcourt and others 1986, Foster 1992, McNab and Avers 1994, Snetsinger and Ventura 1999, Wisconsin Department of Natural Resources 1995). The relative abundance and precise distribution of presettlement forest types and species are difficult to quantify although various efforts such as the Great Lakes Assessment are underway to do so. In the future, perhaps advanced modeling techniques and increased knowledge about plant physiological adaptations, forest-site relationships, and natural disturbance regimes will shed more light on evolutionary and historical conditions.

Great Lakes Ecological Assessment

The Great Lakes Ecological Assessment is an interagency effort to collect and consolidate new and existing environmental, biological, and socio-economic information in the Lake States. The project is envisioned as one part of an overall program of adaptive planning, management, monitoring, and research supporting ecosystem management. Information on current and historical forest conditions is important in planning for biodiversity conservation. Comparisons of current and past species distribution and abundance can help scientists understand the effects of natural and anthropogenic disturbances such as wind, fire, and resource use. Considerable work has been directed at compiling and analyzing baseline information on historical vegetation and ecological processes (Comer and others 1995, Minnesota 1974, Wisconsin 1976). A generalized map of the Lake States was assembled from digital coverages of plot-level data collected by the General Land Office from 1816 to 1856 in Michigan, 1832 to 1866 in Wisconsin, and 1847 to 1907 in Minnesota (figure 1.5).

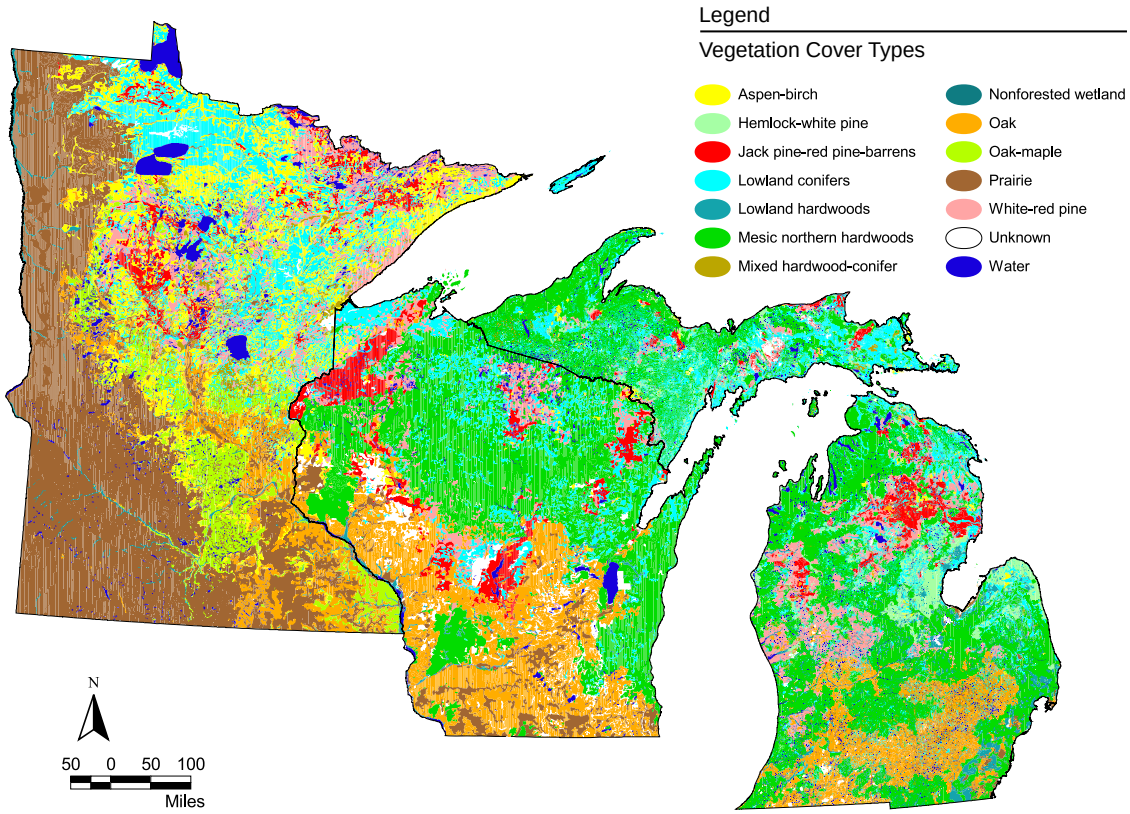


Figure 1.5. **Early European settlement vegetation in the Lake States**. The estimated range of vegetation cover types at the time of early European settlement in the Lake States was similar to what is found today (Cleland 2006).

Other significant areas of study include the impact of past human activities on forest ecosystem composition and projections of the impacts of current activities into the future (Foster 1992). For example, across Provinces 212 and M212, harvesting of pine (*Pinus* spp.) and other conifer species during European settlement reduced native seed sources needed for their regeneration. Subsequent slash fires often further reduced reproductive success and allowed more fire-tolerant deciduous species such as maple (*Acer* spp.), beech (*Fagus* spp.), birch (*Betula* spp.), and ash (*Fraxinus* spp.) to establish. This resulted in a reduced conifer component across the landscape, and reduced vigor and productivity in hardwood stands established on infertile sites more suited to conifers. Fire suppression in fire-dependent ecosystems and herbivory (e.g., deer browsing) in oak (*Quercus* spp.), northern white cedar (*Thuja occidentalis*), and hemlock (*Tsuga* spp.) are other situations with potential to affect forest type composition and distribution.

Urban forests are forested ecosystems characterized by a high concentration of human influences. 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 1.6). Metropolitan or urban areas are usually used to approximate the extent of urban forest because ecological maps are not available. Metropolitan 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). 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.

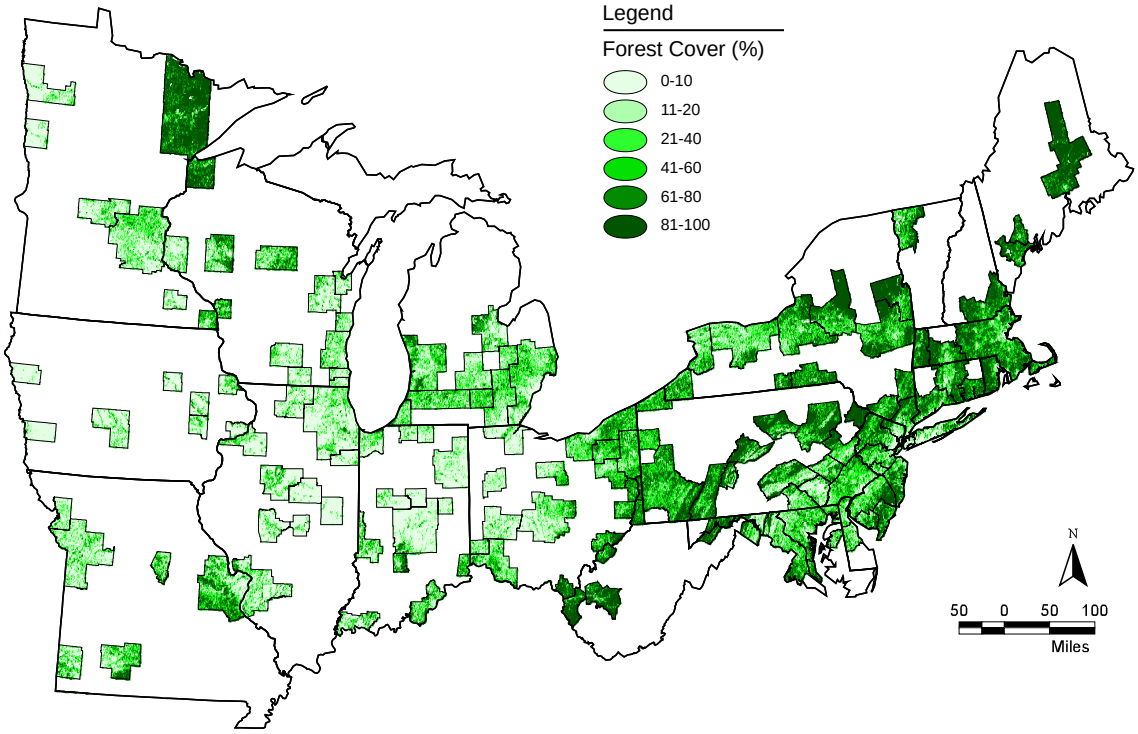


Figure 1.6. **Forest cover in metropolitan areas**. Most metropolitan areas in the Northern United States contain areas with over 40 percent forest cover (Dwyer and others 2000).

Trees and ground cover, buildings, infrastructure (roads, utility corridors, drainage), wildlife, and human populations in urban areas affect the physical and biological diversity of urban forests. The movements of wildlife, people, insects, and diseases are affected by the pattern of land cover and land uses at the local and regional level. Surprisingly, the amount of tree cover in cities in the Northern United States is expected to increase as the size of cities increases in the short term because vacant land in the inner cities has a tendency to naturally revert to trees. The average tree canopy cover for both metropolitan areas (33.4 percent) and urban areas (27.1 percent) is close to that for all land in the coterminous United States (32.8 percent) (Dwyer and others 2000). The type of tree cover in urban forests varies with regional environmental conditions. Urban areas have exotic and hybrid ornamental species, but native species are most prevalent.

Natural Community Classification and Ranking

The State Natural Heritage Programs, The Nature Conservancy (TNC), and the Association of Biotic Inventory cooperatively developed a taxonomy of terrestrial plant communities called the **U.S. National Vegetation Classification (US NVC)** for use in biological diversity conservation planning (Anderson and others 1998, Grossman and others 1998). This classification represents a comprehensive standardized compilation of information on vegetative communities throughout the United States and provides information that the FIA inventory of forest cover does not. It seeks to catalog the full complement of trees, shrubs, herbs, ferns, mosses, algae, and other plants, animals, and organisms such as fungi, protozoa, and bacteria that compose a natural community. Under the system, a **natural community** is defined as an assemblage of species that is found under similar habitat conditions and disturbance regimes. An example natural community description is presented in appendix 1–C.

Communities can be identified at different levels of detail. The **association** is the most detailed level of classification in the US NVC. At the association level, each community is identified by its vegetative assemblage (trees, shrubs, and herbaceous species) and vertical structure (ground, midstory, and overstory flora), and is further characterized by describing the associated environment, ecological processes, and fauna. Associations can have broad or limited geographic ranges. They may occupy small, discrete areas or extensive areas. Abundance and distribution patterns differ by community among ecological units. Different communities occupy a given site over time.

The US NVC associations are categorized into seven broad taxonomic classes: forest, woodland, shrubland, dwarf-shrubland, herbaceous, nonvascular, and sparse vegetation. The US NVC **forest class** is distinguished by land having trees with their crowns overlapping, generally forming 60 to 100 percent of the cover. The **woodland class** has open stands of trees, with crowns not usually touching, generally forming 25 to 60 percent of the land cover. Shrubland, dwarf-shrubland, and herbaceous communities can also have trees as a minor component.

The Northern United States contains 787 associations or roughly 16 percent of 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

diversity is composed of forest and woodland communities. A total of 412 forest and woodland types exist in the Northern United States. These account for roughly one-twelfth of the community diversity in the country (table 1.4).

Table 1.4. **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.

The relative contribution of forest and woodland types to community diversity on an ecosystem basis is substantial. They account for between 34 and 65 percent of the community diversity in provinces in the Northern United States (figure 1.7). The highest percentages occur along the Appalachian Mountain Chain, the lowest in the Prairies, as expected.

The total number of occurrences and the total area occupied by a natural community are key factors for setting priorities for biological diversity conservation and restoration. The Nature Conservancy and State Natural Heritage Programs have developed a ranking system that considers these factors plus condition of occurrences, threats, degree of decline from historical extent, degree of alteration of the supporting natural processes, and the environmental specificity exhibited by the type (Grossman and others 1998) (appendix 1–D). **Conservation status ranks for natural communities** are assigned by applying these criteria at global, national, and State scales. Communities that are ranked globally as critically imperiled (G1), imperiled (G2), or vulnerable (G3) are referred to as **rare associations** or **rare communities** for this report. The remainder of the communities are classified as apparently secure (G4), secure (G5), unrankable (GU), or unranked (G?). A list of the rare forest and woodland associations is in appendix 1–E.

There are 309 rare associations in the Northern United States, 43 percent of which are forest and woodland associations (table 1.5). Over half of the rare forest communities fall in the deciduous forest subclass, roughly a third are evergreen forest, and the rest are mixed deciduous-evergreen forest. No natural communities are known to have been eliminated to date. Rare forest and woodland associations represent 16 percent of the 787 associations known to occur in the region.

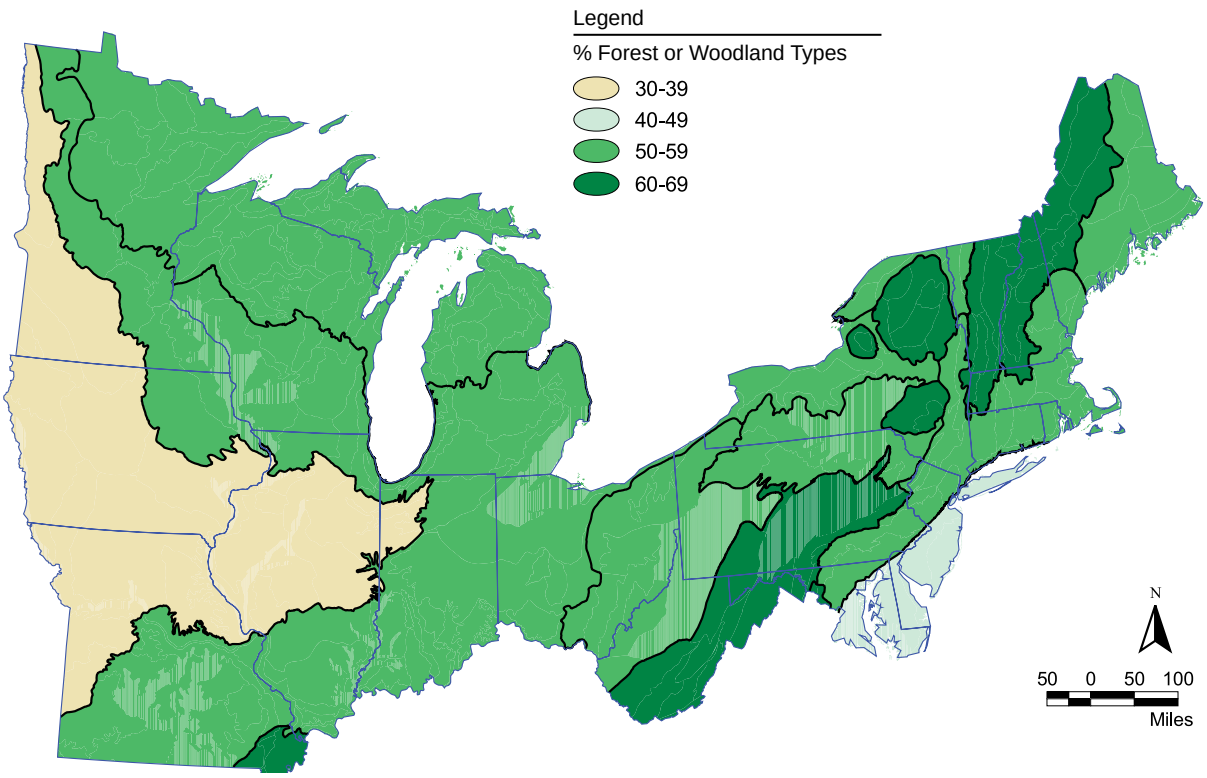


Figure 1.7. **Forest and woodland associations as a percentage of known community types in each province.**[1] Forest and woodland associations contribute substantially to community diversity (Source: TNC 1998).

[1]Provinces are displayed in figure 1.2.

Table 1.5. **US NVC 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**

The reasons for rare status differ by community and region. Once-common or -extensive prairie and wetland communities have been converted to agriculture or urban uses. For example, small unique fens, bogs, and swamps of limited extent are listed for all provinces. Drainage, land conversion to agriculture, and fire suppression have been particularly important in the farm belt of Provinces 251 and 222. Many, but not all, rare forest and woodland communities in the Northern United States are small and historically of limited extent. Some occur at high elevation, others along the Atlantic coast and in barrens and bluffs. Fire suppression is important for

some communities with fire-dependent trees such as pitch pine and oak. Some floodplain forests, particularly in the southern portion of the assessment area, are also on the list of rare communities. Noss and others (1995) estimated that more than 99 percent of the lake plain wet prairie habitat in Michigan has been lost and that in New York, probably 98 percent of the serpentine barrens, maritime heath land, and pitch pine-heath barrens have been lost.

Rare forest and woodland communities account for between 6 and 28 percent of all US NVC associations found in provinces of the Northern United States (figure 1.8). In provinces composed of more than 50 percent forest land (see figure 1.3), they account for between 9 and 23 percent of the forest and woodland associations present. In provinces with less than 50 percent forest land, they account for between 29 and 43 percent of the forest and woodland associations present.

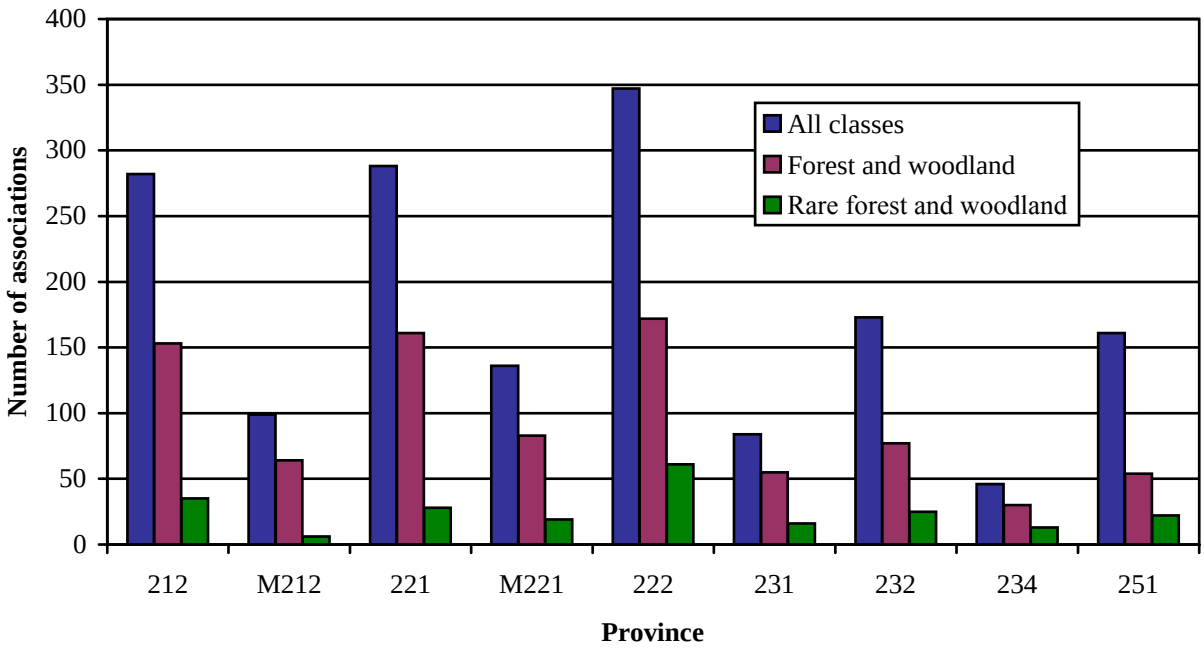


Figure 1.8. **Rare and common forest and woodland classes relative to all natural community classes**. On average, rare forest and woodland types comprise 14 percent of all U.S. National Vegetation Classification associations found in provinces of the Northern United States (TNC 1998).

Indicator 2. Extent of area by forest type and by age class or successional stage

Trees have different regeneration and growth habits, mature at different rates, and die at different ages, so, for example, a sugar maple (*Acer saccharum*) tree can persist with vigor for 250 or more years whereas an aspen (*Populus* spp.) tree will generally enter senescence at less than 100 years. Thus, successional stages cannot be measured strictly by looking at forest age, although it is helpful.

As a forest ages, pioneer species such as aspen, birch, and cherry (*Prunus* spp.) are often replaced by more long-lived deciduous and coniferous species owing to natural succession.

Therefore, a shift in age-class distribution sometimes signifies a shift in forest type distribution across the landscape. For example, in the Northern United States, aspen-beech-birch is considered an early successional type that may ultimately succeed to maple-beech-birch, oak-hickory, or spruce-fir types depending on site potential.

From a biodiversity perspective, a variety of successional stages and a balanced age class distribution is considered desirable across a landscape. The communities of plants and animals that inhabit any given site will vary with the habitat provided.

Although there is no direct inventory of the extent of forest by successional stage that covers the Northern United States, the USDA Forest Service has tracked changes in forest land acres by forest cover type and age through the FIA Program (table 1.6). Therefore, age class information is used as a surrogate measure in this report (USDA Forest Service 1999b).

Table 1.6. **Acreage of forest land by age class and forest type in the Northern United States** [1 2] (USDA Forest Service 1999b[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), although maple-beech-birch, spruce-fir, aspen-birch, white-red-jack pine, and oak-hickory cover type groups are known to occur there.
[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.

In the Northern United States, over 9 percent of the forest land is shown as occurring in mixed-age stands, although the actual acreage is greater. **Mixed-age stands** contain trees that range in size from seedlings to large trees. The seedlings of shade-tolerant species (such as sugar maple, beech, and ash) and midlight-tolerant species (such as white pine [*Pinus strobus*] and hemlock) can persist in the understory of a mixed-aged stand until some disturbance opens the canopy and they grow into a more prominent position. The FIA units in the Northeastern and North Central regions (figure 1, page 9) use different methods to inventory stand age. In the North Central FIA region, mixed-aged stands are assigned to a specific age based on the dominant and codominant trees in the stand. In the Northeastern FIA region, a forest stand is either assigned a specific age or is classified as a mixed-age forest. Thus the regional total underestimates the current acreage of mixed-age forest.

An estimated 76 percent of the forest stands are less than 80 years old, and there is little representation of very old stands. Owing to the natural maturation of the forest in the Northern United States, there is potential to increase the acreage of the older stands in the next few decades. For example, Schmidt and others (1996) noticed that forest acreage for stands more than 120 years old in the Lake States increased from about 812,000 acres in the late 1970s to almost 1,150,000 acres in the 1990s.

Natural disturbance, timber harvesting, and natural aging are the factors that move forests to early successional stages. Types of natural disturbance common across the Northern United States include small-scale gaps in the forest formed by the fall of individual trees, small fires, and ice storms of varying sizes. Somewhat larger fires tend to occur in the oak-hickory forest 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 commonly in the Midwest. Most managed forest stands in the Northern United States are harvested between 60 and 120 years of age: aspen-birch stands are harvested closer to 60 years, and maple-beech-birch stands are harvested closer to 100 or 120 years. Schmidt and others (1996) found that a quarter of the timberland over 80 years old in the Lake States experienced disturbance within the 13-year period 1980–1993.

Variation in urban tree stem diameters provides some indirect information on age class distribution in urban areas. The majority of trees in urban areas are in the small diameter classes, although there are some differences in age by land use. For example, institutional lands and residential lands may have more large trees than industrial and agricultural areas as residents and groundskeepers tend large trees and discourage new growth. Vacant urban lots in this region tend to naturally regenerate trees over time (Dwyer and others 2000).

Old Growth

Different definitions of **old growth** abound, ranging from mature virgin forested areas to stands managed for old-growth characteristics regardless of degree of human intervention (Leverett 1996). Some definitions focus on the age or size of the trees, some 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 upon 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, although it is generally believed that there is more than has been reported to date. Davis (1996) identified sites totaling roughly 1,296,000 acres of old growth in the Northern United States, roughly 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' figures include age as a criterion.

When age is a primary criterion in classifying old growth, the acreages increase. For example, in Michigan, Minnesota, and Wisconsin, Frelich (1995) identified 465,000 acres of noncommercial old growth, mostly black spruce-tamarack (*Picea mariana-Larix laricina*) and northern white cedar, that would result in an over-80-percent increase in the total acres of old

growth not included in a earlier survey (Davis 1993) for those States. The swamp conifers, although old, were left undisturbed because of their small size as well as their inaccessibility.

Old growth is important for certain types of species diversity. It also has ecological value as a reference ecosystem. Study of all types of old-growth ecosystems is seen as particularly important to answer questions related to forest succession, nutrient recycling, disturbance cycles, patch dynamics, and the mix of symbiotic, competitive, and parasitic relationships among biota. What is learned from these forests is expected to help with the management of other forested areas. Also, the study of old-growth ecosystems may hold the answers to questions about the long-term effects of human intervention in natural systems.

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 land (Tyrrell 1996). This allocation is in addition to any old growth that exists on land designated as wilderness or research natural areas.

Indicator 3. Extent of area by forest type in protected area categories as defined by International Union for the Conservation of Nature or other classification systems

Humanity depends on natural systems for survival. The diversity of life forms and the interactions between them and the environment are the reasons the systems function so effectively. Protection of these functioning systems is a key reason for developing strategies to protect ecosystem diversity. Private landowners and public land managers can contribute to forest ecosystem diversity. They can manage their lands in ways that maintain their inherent ecological potentials, provide habitat for wildlife, and contribute to land use patterns that allow for movement of species across the landscape. It will take concerted public and private efforts to maintain that diversity, as roughly 3.9 million private landowners own 78 percent of the forest land in the Northern United States.

Public agencies have a role in monitoring and communicating information on the status of biological diversity and are central to efforts to ensure that the full array of ecosystems in an area are present. Systems of reserved lands are commonly used to ensure that representative examples of all ecosystem types are preserved in perpetuity. Protection of a representative array of natural habitats and intact ecosystems should result in protection of examples of most species and genetic diversity as well. Species that fall through this coarse filter can be targeted by the fine filter of protecting lands necessary to the conservation of a particular species.

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 industries to dedicate some lands to the protection of species and ecosystems. Private landowners may enter into agreements such as conservation easements—legal contracts that provide some compensation to landowners for the dedication of their land or property rights to public or private organizations.

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). The IUCN identified six common land management objectives compatible with some degree of biological diversity protection and is in the process of categorizing existing public lands based on authorizing legislation (table 1.7). The categories range from strict protection to management in conjunction with other uses.

Table 1.7. **Northern United States land in International Union for the Conservation of Nature protected area categories** (IUCN 1994, UNEP-WCMC 2002).

Protected area category	Objective	Examples	Acres
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

Reserved forest land inventoried by the FIA Program includes IUCN Category I through IV lands but not Category V lands. **Reserved forest land** is defined by the FIA Program as land withdrawn from timber utilization by statute or administrative regulation by some level of government. Under this definition, roughly 5 percent (8.2 million acres) of the forest land in the Northern United States is currently reserved. The majority of reserved forest land is in Provinces M212 and 212 (figure 1.9). The amount of reserved forest land has more than doubled since 1992 when the total acreage was estimated at 2.3 percent of total forest land acres (Powell and others 1993).

Federally administered public land in the Northern United States is limited. The USDA Forest Service has the largest land holdings among Federal agencies in this region. It administers 11.9 million acres among 15 national forests and grasslands (USDA Forest Service 1998b). The National Forest Management Act of 1976 (P.L. 94–588, 16 U.S.C. 1600 (note)) requires the Forest Service to "provide for diversity of plant and animal communities

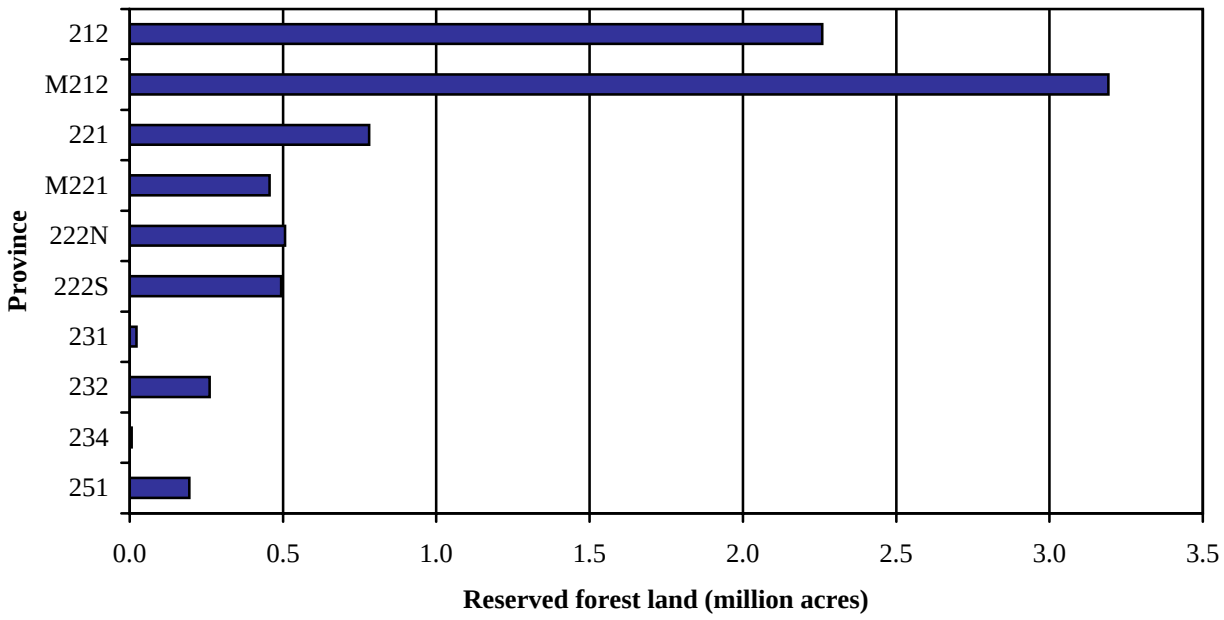


Figure 1.9. **Reserved forest land by province**.[1] The majority of reserved land in the Northern United States is in Province 212 (Laurentian Mixed Forest) and M212 (Adirondack-New England Mixed Forest-Coniferous Forest-Alpine Meadow) (USDA Forest Service 1999b[2]).

[1]Provinces are displayed in figure 1.2.
[2]Inventory follows methods in Hansen and others (1992).

based on the suitability and capability of the specific land area in order to meet overall multiple use objectives . . .” Therefore, IUCN categories apparently include the range of management objectives applied to nearly all national forest lands. The specific category depends upon the designated land allocation and management prescription. For example, Federal wilderness and research natural areas are included in IUCN Category I. If the majority of acreage of Forest Service-administered lands suited for timber management is included in IUCN Category V, then the IUCN reserved forest total may increase to roughly 8.5 percent of forested land in the Northern United States.

The USDA Forest Service National Wilderness Preservation System, the Research Natural Areas Program, and State natural areas and other programs contribute to biodiversity protection in the Northern United States.

The Wilderness Act of 1964 (P.L. 88–577, 78 Stat. as amended; 16 U.S.C. 1131(note), 1131–1136) established the National Wilderness Preservation System composed of federally owned areas designated by Congress. A **wilderness area** is “an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain; an area of underdeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation and which is protected and managed so as to preserve its natural conditions.” There are 1,595,374 acres of wilderness in 50 wilderness areas on national forests across the Northern United States (see appendix 7–C).

A **research natural area** (RNA) is an area that is to be permanently protected and maintained in a natural condition. Research natural areas are designated by Congress to

include unique ecosystems or ecological features, rare or sensitive species of plants and animals and their habitat, and high-quality examples of widespread ecosystems. There are 23,583 acres in 41 RNAs on national forests in the Northern United States (see appendix 7–D). The RNA program strategy in the USDA Forest Service's Eastern Region is to preserve representative US NVC communities and ecological land types in each Forest Service subsection unless they are already adequately protected by other means (figure 1.10).

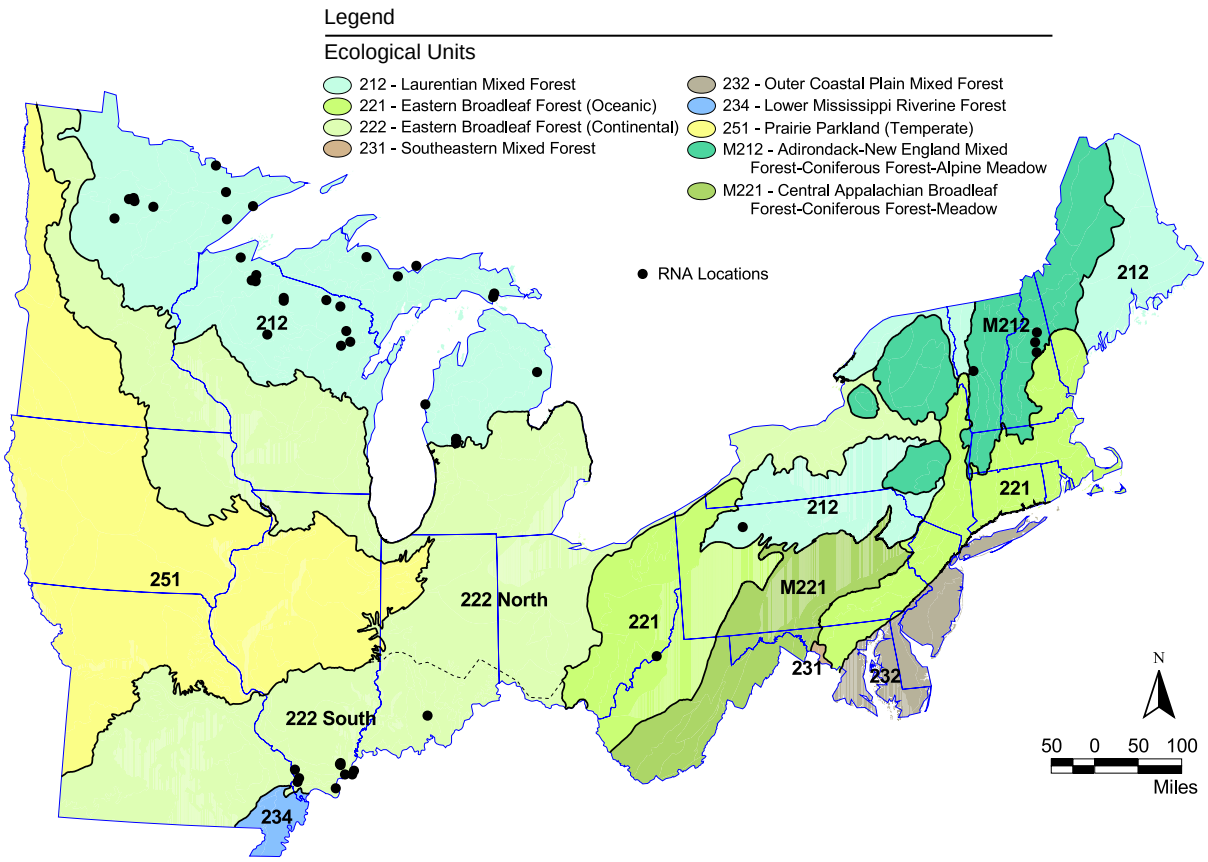


Figure 1.10. **Location of USDA Forest Service research natural areas (RNAs) in the Northern United States**. RNAs preserve representative examples of U.S. National Vegetation Classification communities and ecological land types on national forest land.

A total of 436 natural areas with 181,580 acres had been designated through State-level natural area programs as of the last survey in 1977 (TNC 1977).

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 831 local land trusts operating in the Northern United States (Land Trust Alliance 1998). The Land Trust Alliance census defines a **land trust** as a "nonprofit organization that, as all or part of its mission, works to conserve land by undertaking or assisting direct land transactions—primarily the purchase or acceptance of donations of land or easements" (Land Trust Alliance 1998, p. v). These local land trusts affected 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 1.11). Of these trusts, 250 listed conservation of rare species habitat as one of their conservation objectives.

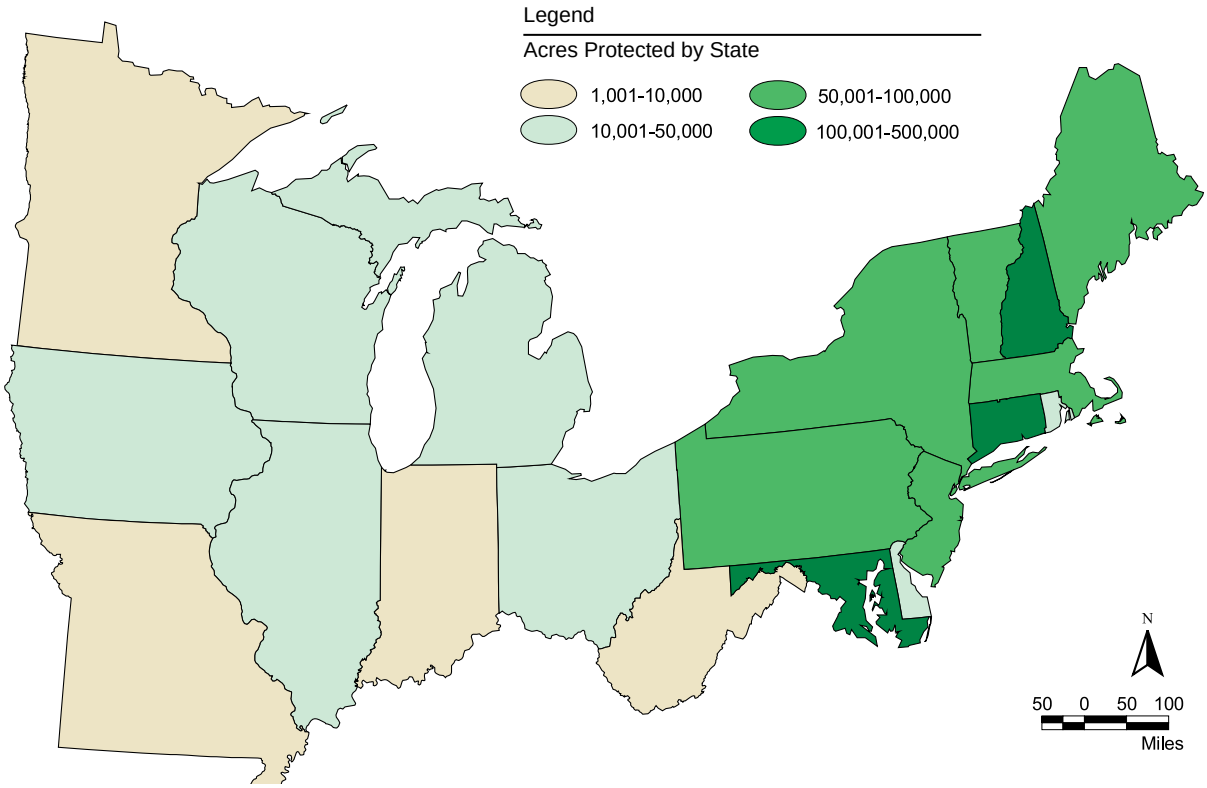


Figure 1.11. **Acres protected by land trusts through 1998**. Land trusts play an important role in biodiversity protection, especially in the eastern part of the Northern United States (Source: Land Trust Alliance 1999).

The Nature Conservancy and the Trust for Public Land are two private organizations operating at a national level. The Nature Conservancy is the largest national land trust with biological diversity protection as part of its mission. Since its founding in 1951, TNC has encouraged conservation of over 10 million acres. It has retained ownership of less than a million of those acres and transferred 2.3 million acres to various government agencies. The Trust for Public Land has conserved roughly a million acres.

Forest industry landholdings may contribute through designation of special management areas. The American Forest & Paper Association's Sustainable Forestry Initiative requires members to identify and manage land of ecological, geologic, or historic significance in a manner that accounts for their special qualities. One example was the designation of a 76-acre lowland bog in Vermont dedicated by Champion International and the U.S. Fish and Wildlife Service in memory of Mollie Beattie, former director of the U.S. Fish and Wildlife Service.

In the Northern United States, the actions of private individuals are critical because of the amount of land they control. Some privately owned forest land is undoubtedly "protected" in every sense of the word, but it is safe to say that few private individuals conduct deliberate and comprehensive planning for biodiversity. Private action could include control of exotic species and pests, management to protect rare species, harvest in a way the preserves positive genetic traits, and activity management that considers wildlife needs for travel corridors, nesting habitat, etc. In 1994, 29 percent of private forest landowners responding to a survey stated they never intend to harvest their forest land (Birch 1996b). Of the landowners that do not plan to harvest, 95 percent own less than 50 acres of forest land (Birch 1996b). Many of these small tracts are associated with other activities, such as recreation or residences, which increases the likelihood they will not be harvested. There can be differences, however, between what private landowners say they will do and what they actually do (Turner and others 1977).

Inaccessible tracts and tracts with other physical conditions such as wetness probably provide some de facto biological diversity protection because disturbance by humans is limited. Timber harvest operability ratings may identify many of these lands. **Operability** is defined as the ease or difficulty of managing or harvesting timber because of physical conditions. For example, in Michigan, with technology in use in 1980, 40 percent of the total area of timberland fell into operability class III, which states site preparation equipment can be used except for a 10- to 30-day period during spring break up and about 1 to 3 days following a significant rains during the growing season (Hansen and Hahn 1987).

Indicator 4. Extent of areas by forest type in protected areas defined by age class or successional stage

Reserved lands include some stands in each of the forest cover type groups and in all inventoried age classes, although not all forest cover type groups are represented in all age classes (table 1.8). Roughly 76 percent of the inventoried stands 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. The majority of reserved forest land in the Northern United States is classified as being in the oak-hickory and maple-beech-birch types (figure 1.12) (USDA Forest Service 1999b).

Indicator 5. Fragmentation of forest types

Fragmentation is the breaking up of large and continuous ecosystems, natural communities, and habitats into smaller areas surrounded by altered habitat, developed land, disturbed land, or aquatic substrate. A reference to a forest fragment may refer to either a patch of forest land or a forest patch of a certain age or structure that provides some aspect of a species' habitat. The distribution of natural communities across an unaltered landscape will reflect differences in soil, climate, moisture, slope, aspect, and disturbance regime. For this reason, landscapes naturally exhibit variations in forest cover and fragment size, and logically, the effects of fragmentation will also differ among landscape settings.

Table 1.8. **Forest cover type group and age class of reserved land in the Northern United States** [1 2] (USDA Forest Service 1999b[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	1,197.8	728.8	768.6	501.8	401.2	452.0	55.5	75.7	29.1	6.4	4,216.8
41–80	424.4	218.0	29.4	28.7	26.7	74.4	5.1	63.9	3.4	—	873.9
81–120	70.8	125.3	27.3	43.3	32.8	15.7	12.6		0	0	327.7
121–160	—	1.2	—	27.8	—	—	—	—	—	—	29
160+	—	1.2	—	1.2	—	—	—	—	—	—	2.4
Mixed	9.6	18.5	43.2	33.7		13.4			5.4	3.1	126.7
Total	**1,702.6**	**843.7**	**1,117.7**	**636.4**	**460.6**	**555.4**	**73.2**	**139.7**	**37.8**	**9.5**	**5,576.5**

[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.

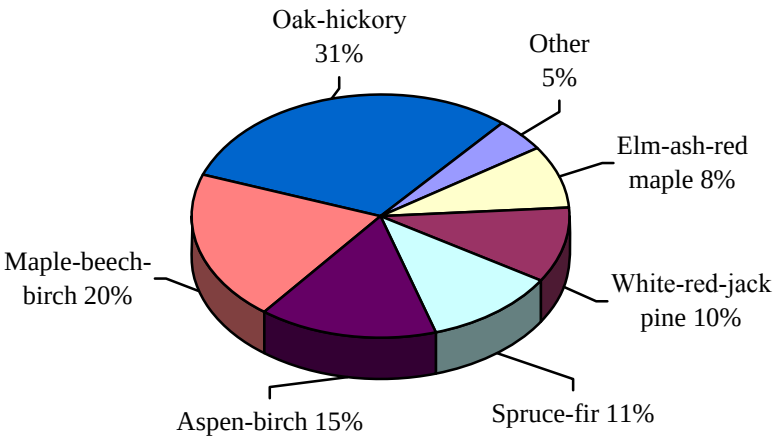


Figure 1.12. **Reserved forest land by forest cover type in the Northern United States.**[1] The oak-hickory and maple-beech-birch forest cover types comprise over half of the reserved forest land in the Northern United States (USDA Forest Service 1999b[2]). "Other" includes oak-gum-cypress, oak-pine, and loblolly-shortleaf pine.

[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).

The fragmentation cause of greatest concern today is the permanent and long-term conversion of forest land to development. According to the USDA Natural Resources Conservation Service, nearly 3.7 million acres of forest land was converted to developed land between 1982 and 1997 (USDA NRCS 2000). This is roughly 45 percent of the nearly 8 million acres developed during that period in the Northern United States (figure 1.13, appendix 1–F). Pennsylvania (620,500 acres), Michigan (372,900 acres) and Massachusetts (367,800 acres) have the highest losses to development; Iowa has the lowest (14,800 acres) (appendix 1–G). Regionally, long-term losses of forest land for the period are masked by an increase in total forested acreage owing to reversion of, primarily, pastureland and some cropland to forest cover, mainly in the Lake and Central States (appendix 1–H). Historically, forest land conversion to agriculture was the most significant loss. Now, suburbanization is the primary cause of deforestation on rural landscapes, surpassing conversion to agriculture (Zipperer and others 1990).

Urban and suburban expansion reduces the amount of land available for the production of forest goods and alters associated environmental services. Over time, the concurrent impacts of resource demand and limited supply can result in significant management challenges and affect the amount and quality of the goods and services available in the future.

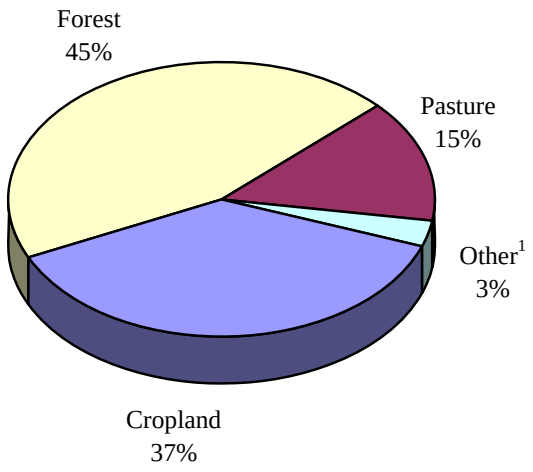


Figure 1.13. **Land developed in the Northern United States, 1982–1997**. About 45 percent of the nearly 8 million acres developed was forest land (USDA NRCS 2001).

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

Negative impacts of fragmentation owing to development include decreased:

- Forest health and diversity;
- Viability of forest as an economic unit;
- Stream stability, health, and water quality;
- Habitat for interior dwelling wildlife species;
- Recreation access and use; and
- Community livability, economic diversity, and quality of life.

Habitat deforestation is considered to be the most serious threat to biological diversity and a primary cause of species decline (DeGraaf and Healy 1990, Wilcove and others 1986). Forest fragmentation can involve a simultaneous decrease in the average size of habitat patches, an increase in the average distance between patches, and an increase in edge effects. As a general rule, large fragments have more wildlife species and can sustain larger wildlife populations than small fragments (Hunter 1996). As the amount of fragmentation increases, species populations may become isolated, and the migration of individuals and populations between areas of suitable habitat becomes more difficult.

An expanding human population, changing land ownership dynamics, and sprawling development patterns have important implications for forest resources in the Northern United States. Between 1978 and 1994, overall forest area increased by 14 percent. Parcelization, generally associated with fragmentation, is the process that divides a single block of forest ownership into two or more ownerships. Adjacent ownerships may or may not be in similar

habitat types. In 1994, there were 3.9 million private forest landowners holding 130 million acres of forest land in the 20 Northern States, an increase of 600,000 owners over 1978. Ninety-three percent of those ownerships contained less than 100 acres of forest land although together they held more than a quarter of all private forests (Birch 1996a).

Average stand area is the average size of forest tracts where a forest tract is continuous and of related or similar forest type, ownership, landform, and stand age. Average stand areas of less than 10 acres currently represent almost 40 percent of the total area of timberland in the Lake States. Providing contiguous habitat and meeting other goals is more difficult with many small stands versus a few large stands. Less than 4 percent of that timberland in the Lake States is found in tracts larger than 640 acres (Schmidt and Raile 1999).

Clearcutting and partial harvest techniques tend to temporarily fragment habitat by affecting the age class distribution of patches or by causing some change in habitat type, such as from northern hardwood to aspen-birch forest. For example, from the mid-1970s to the mid-1990s, roughly 19 percent of Lake States timberland acreage was affected by either clearcutting, partial harvest, or natural disturbance. The disturbance rate averaged more than a million acres per year. Natural disturbances accounted for 30 percent of the acreage (4 million acres) (Schmidt and Raile 1999).

The overall effects of habitat fragmentation on wildlife may be difficult to sort out at first, because tradeoffs are inherent among species with varying life strategies, and wildlife populations fluctuate naturally over time. Some species of forest songbirds thrive only on very large patches of mature forest habitat, whereas others flourish in younger, more fragmented habitat. Physical changes in microclimates can occur as fragmentation affects solar radiation, wind, and water fluxes (Saunders and others 1991). Increases in soil temperature and modified hydrology after harvest can affect habitat for species such as salamanders. Edge effects occur at the interface of two or more habitat types; they can be beneficial for some species and detrimental for others. A large amount of edge can result in increased competition, predation, and parasitism among organisms. Exotic species incursion is closely associated with amount of forest edge.

Roads are harbingers of fragmentation. They provide access for timber harvest, intensive recreational development, and urbanization, and create edge effects. For example, in the Lake States, 68 percent of timberland is within a half-mile of a road, and thus, vulnerable to fragmentation (Schmidt and Raile 1999). In the Mid-Atlantic region, the U.S. Environmental Protection Agency led an ecological assessment of landscape conditions expressed by environmental indicators, including forest fragmentation, forest edge habitat, interior forest habitat, and largest forest patch in relation to the amount of forest cover. The results showed that the pattern of forest loss is as important as the amount lost (Jones and others 1997).

Species Diversity

Species are generally defined as groups of interbreeding natural populations or groups of populations with the potential to interbreed. Individuals in a population share a common gene pool. For example, brown bears (*Ursus arctos*) and black bears (*Ursus americana*) in America are separate species because they do not interbreed, whereas brown bears in Eurasia and America are considered one species even though they have been separated physically

for nearly 10,000 years (Hunter 1996). Species include plants, invertebrate animals, lichens, fungi, bacteria, and other microorganisms, as well as vertebrates, which garner the most attention.

Wildlife Diversity

- Globally, an estimated 1.75 million species are known (Master 1991).
- Of identified species, the majority are insects (53 percent), animals (20 percent), higher plants (18 percent), and fungi (5 percent). The remainder includes viruses, monera, algae, and protozoa (4 percent) (Hunter 1996).
- In the United States, scientists have described and named more than 100,000 native species (TNC 1997).

Species richness is a measure of biological diversity based on the total number of species inhabiting a defined area. Figure 1.14 depicts the pattern of bird species richness based on counts from breeding bird surveys. Not all species are valued equally in species biological diversity management. One consideration is the number of taxa represented in an area. For example, management of species of the same taxa, such as gray wolves (*Canis lupus*) and coyotes (*Canis latrans*), is qualitatively different from management for smallmouth bass (*Micropterus dolumieu*), a species of a different taxa. Another value is the degree of rarity. Generally, a rare species will attract more attention than a common species.

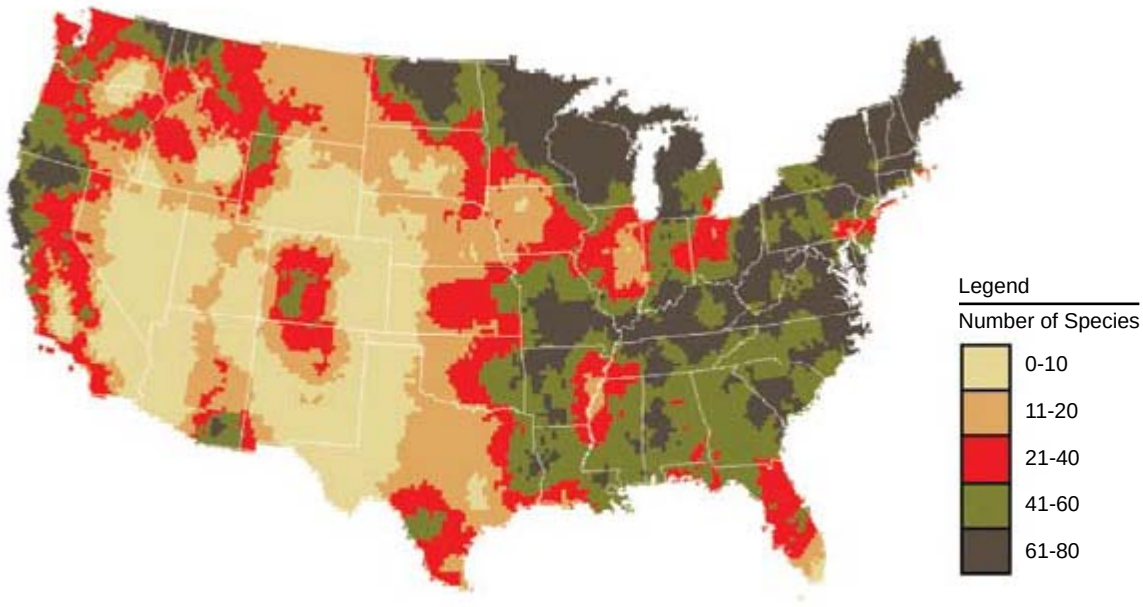


Figure 1.14. **Pattern of bird species richness based on species counts observed during historical breeding bird surveys** (survey method in Droege 1990). Bird species richness is high in most of the Northern United States relative to the rest of the Nation (Flather and others 1999).

Species range and abundance are structural components of species diversity, and the variety of ways that plant and animal species interact with each other and their environment are functional characteristics. For example, wolves aggressively exclude coyotes from suitable habitat, but neither of these mammals has much influence on the distribution or abundance of smallmouth bass. The size of the area assessed is another important consideration in interpreting measures of species diversity and in determining priorities for conservation.

Species may be native or nonnative. Nonnative (exotic) wildlife species are often opportunistic and aggressive, and may prey on native species. Naturalized exotics may decrease the natural diversity of native wildlife or change community species composition (Harty 1993). Examples of nonnative vertebrate species that have been introduced into the Northern United States include the house sparrow (*Passer domesticus*), the European starling (*Sturnus vulgaries*), the brown-headed cowbird (*Molothrus ater*), and the ring-necked pheasant (*Phasianus colchicus*) (Ehrlich and others 1988).

Exotic species can cause problems for native species and forest managers. For example, prairie chickens (*Tympanuchus cupido*) could become extirpated in Illinois owing to parasitism of nests by ring-necked pheasants (Vance and Westemeier 1979). Native species can also be a source of concern. For example, the brown-headed cowbird has expanded its range from the Great Plains to the Eastern United States and dramatically increased in population. The cowbird affects of a variety of birds by parasitizing their broods (Robinson 1996).

Indicator 6. The number of forest-dependent species

Forest-dependent species require the use of forested habitat at some point in their life cycle. The ovenbird (*Seiurus aurocapillus*) and the American marten (*Martes americana*) are examples of species that require forested habitat during their entire life cycle (DeGraaf and Rudis 1986). There is no definitive list of forest-dependent species in the Northern United States. 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 the mammal and reptile species can be sighted on forested land, although they may or may not be dependent on that habitat for survival (USDA Forest Service 1997a).

Some indications of the importance of forests to wildlife in the Northern United States can be gleaned from management materials. Of 389 vertebrate species (71 percent birds, 17 percent mammals, 12 percent reptiles/amphibians) found in the northern forests of Michigan, Minnesota, and Wisconsin (Western Province 212), 37 percent were common, 10 percent were occasional, and 53 percent were uncommon there (Benyus and others 1992). Thirty-three species were classified as highly versatile, using deciduous, coniferous, and mixed forest types; 204 had intermediate versatility; and 152 were restricted to specific habitats. Of the forest species, 49 percent used mature forest and 40 percent used young forest. In New England, DeGraaf and others (1992) compiled forest management recommendations for 167 vertebrate species that included birds, mammals and amphibians.

Wildlife species composition changes through time. Trends in land cover and land use are associated with the distribution and abundance of wildlife species owing to the effects on the quantity and quality of their habitat (Block and Brennan 1993, Forman 1995, Janetos 1997). Wildlife habitat is affected by permanent or temporary losses of forest cover owing to urban sprawl, fire, windthrow, agriculture, and logging. Wildlife is affected by indirect effects as well. For example, forest-dependent Neotropical migratory birds can be affected directly by loss of forest habitat from development (in this country or others), but also by isolation of populations, isolation of individuals of a population, and increased predation and parasitism owing to forest fragmentation. Opportunities to counter these negative trends include creating wildlife habitat and enhancing existing habitats through forest and landscape planning and management.

Indicator 7. 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

Population viability is the ability of a population to persist or maintain itself over time. Extinction, on the other hand, refers to the irrevocable loss of an element of biological diversity, in this case, a species. Detailed scientific assessments of viability consider the aggregate of conditions encountered by a population over time. For example, the amount, quality, and long-term security of habitat are key considerations. In the Northern United States, degradation or loss of critical habitat (e.g., heron rookeries), isolation of habitat, the introduction of nonnative species, pollution, and poor harvesting practices can affect habitat. Other factors include phases of recruitment, growth, mortality, seasonal fluctuations in biomass, and the persistence and relative dominance of each year's population. Viability assessments, in a sense, are risk assessments.

Another approach to determining conservation status of a species is to try to assess how likely it is that the species will become extinct. State agencies participating in the Natural Heritage Network, and TNC in collaboration with scientific institutions and agencies, routinely conduct assessments of the extinction potential of species (TNC 1997). For these assessments, they use information on total population size and population trends, the extent of habitat, the breadth of a species' geographic range, the number of different populations that exist across that range, and some assessment of human and natural threats to the species and its habitat.

Conservation status ranks for species are assigned by TNC at global, national, and State levels. Global ranks are used in this report. 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 allow an assessment of their global conservation status. Species ranked presumed extinct (GX) and possibly extinct (GH) are known to have occurred historically but have not been found in recent inventories. Those ranked as critically imperiled (G1), imperiled (G2), or vulnerable (G3) are targeted for conservation. The remainder of the communities are classified as apparently secure (G4), secure (G5), unrankable (GU), or unranked (G?). Conservation status ranks reflect the results of biological evaluation and do not confer legal protection to species evaluated.

The majority of native plants and animals evaluated in the United States and in the Northern United States are secure or apparently secure (figure 1.15) (TNC 1997, TNC and ABI 2000). According to TNC, of 20,439 plant and animal species evaluated nationally, roughly one-third are not faring well. Of 5,869 plant and animal species evaluated in the Northern United States, roughly one-tenth are not faring well. Twenty-five Northern United States species are presumed to be extinct or possibly extinct; of these, six are birds, seven are fish, eight are freshwater mussels, and four are flowering plant species (appendix 1–I). These numbers represent roughly 5 percent of 526 presumed/possibly extinct species identified nationwide. The highest numbers of presumed/possibly extinct species in the Northern United States are found in Illinois, Indiana, and Ohio (appendix 1–J). Extinction rates worldwide are thought to be many times greater than expected natural rates.

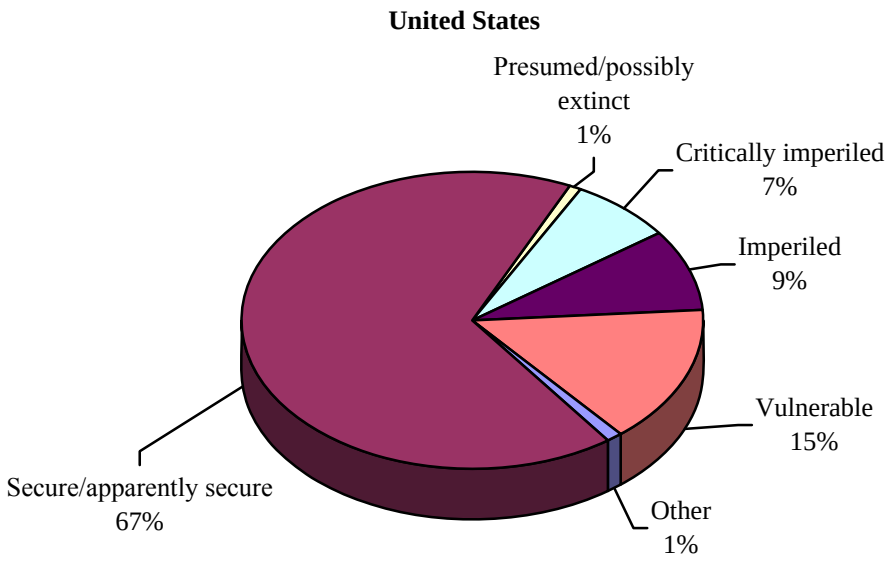
The terms **threatened species** and **endangered species** usually refer to species designated through a scientific and political process under the Federal Endangered Species Act of 1973 (P.L. 93–205, 87 Stat. 884, as amended: 16 U.S.C. 1531–1536, 1538–1540). Under this act, the term endangered species means "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." The term threatened species means "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."

Does the Endangered Species Act make a difference?

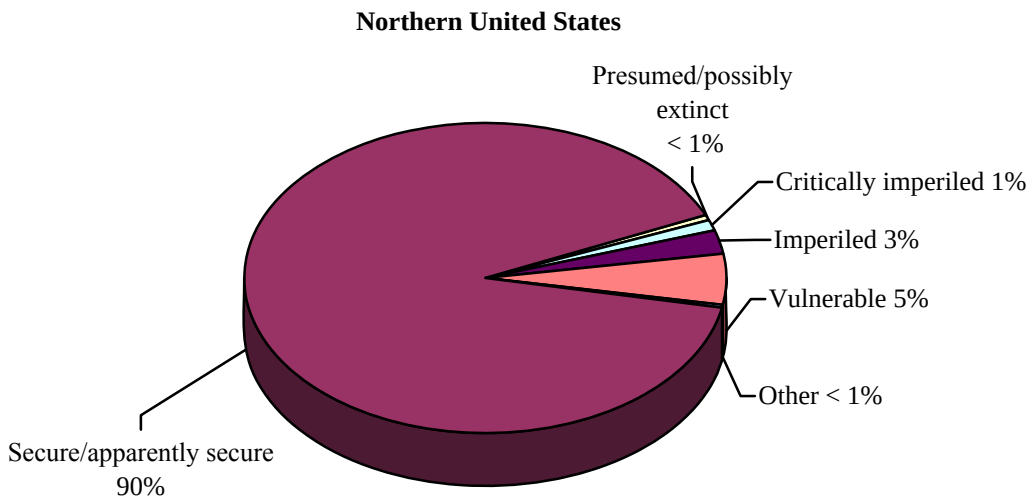
The intent of the Endangered Species Act (ESA) is basically to conserve threatened and endangered species and the ecosystems that provide necessary habitat.

There has been notable recovery of plants and animals that have been threatened or endangered in the Northern United States. The recovery of species such as the bald eagle (*Haliaeetus leucocephalus*), peregrine falcon (*Falco peregrinus*), and small whorled pogonia (*Isotria medeoloides*), to name a few, are due in large part to protection afforded under the Endangered Species Act.

The listing process can be time consuming and public debate contentious. Therefore, not all species are receiving the protection they are entitled to under the ESA (Clark and others 1994). Independent studies indicate that the number of species formally listed under the ESA is fewer than the number that qualifies for listing. For example, of 680 plant species identified as critically endangered by the Center for Plant Conservation in 1988, only 201 were legally protected; of 102 U.S. fish species identified by the International Union for the Conservation of Nature, only 54 were listed under the ESA (Flather and others 1994).



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



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

Presumed extinct	(GX)	Not located despite intensive searches
Possibly extinct	(GH)	Of historical occurrence; still some hope of rediscovery
Critically imperiled	(G1)	Typically 5 or fewer occurrences or 1,000 or fewer individuals
Imperiled	(G2)	Typically 6–20 occurrences or 1,000–3,000 individuals
Vulnerable	(G3)	Typically 20–100 occurrences or 3,000–10,000 individuals
Apparently secure	(G4)	Uncommon but not rare; some cause for long-term concern; usually more than 100 occurrences and 10,000 individuals
Secure	(G5)	Common; widespread and abundant

Figure 1.15. **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.

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. Thirty-eight of these are plants (figure 1.16). The list of species is available in appendix 1–K. Many of these listed species can be found on private land (estimates range from 75 to 90 percent).

Areas in the Northern United States with the most threatened and endangered species are the Atlantic Coast, the Upper Peninsula of Michigan, the Missouri Ozarks, and mountainous West Virginia. The areas with nearly as many threatened and endangered species are the Mississippi River corridor and other river and lake border areas (Flather and others 1999).

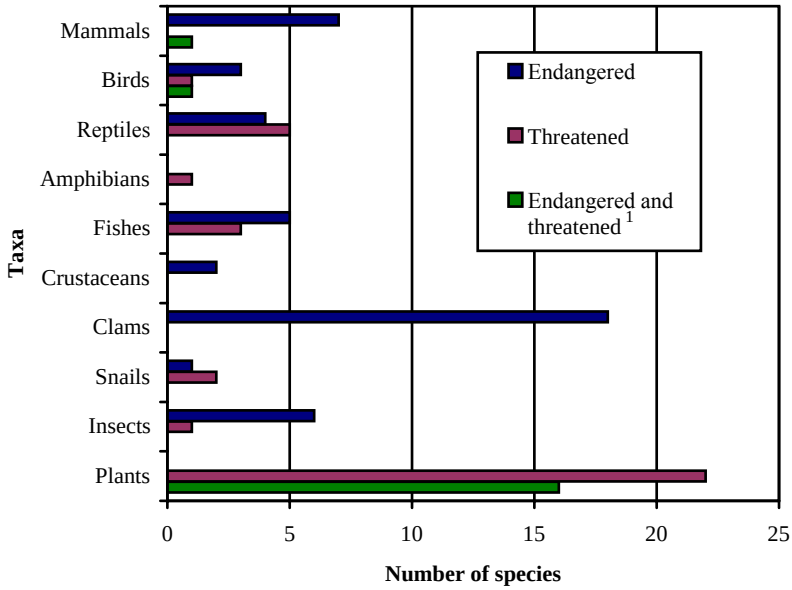


Figure 1.16. **Endangered and threatened species by taxa in the Northern United States** (McLellan 1998, USDI Fish and Wildlife Service 1999a). Of 105 federally listed species, 38 are plants.

[1]Endangered in one part of its range and threatened in another.

Genetic Diversity

Genetic diversity affects the ability of a species to evolve in response to changes in its environment (Soulé 1980). It is an important factor when determining the probability that a species will become extinct (Lande 1988, Lande and Barrowclough 1987). Reduced genetic variation reduces the potential for disease resistance (Frankham 1995, O'Brien and Evermann 1988) and increases the likelihood of inbreeding (Ralls and Ballou 1983; Ralls and others 1979, 1988; Wright 1977) and resulting mutations in individuals (Lynch 1996). Genes determine the form and fitness of an organism. Individuals with a high degree of fitness are important to the conservation of species.

Genes establish the physiology of organisms. They determine species (e.g., Is it a wolf or is it a pine tree?); therefore, the diversity of species is the coarsest measure of genetic diversity. Diversity within a species is the next level of measurement. Within a species, all individuals have the same genes, but the **alleles** (configurations of DNA at a given locus of a chromosome) differ (e.g., a tiger and a tomcat have the same genes but different alleles). Knowledge of these differences provides the basis for measuring genetic diversity among individuals and populations of a species.

A **population** is a collection of individuals of a species that potentially interbreed and share a common gene pool. Some species have greater genetic variation within populations; other species have greater variation among populations. For example, loblolly pine (*Pinus taeda*) is a widespread tree species; its genetic diversity is highly variable among loblolly populations.

Red pine (*Pinus resinosa*) also is widespread, but it exhibits little genetic variation among populations (Taylor and others 1996). Eliminating populations can affect the reservoir of genetic diversity for a species. So in the above example, the loss of a population of loblolly pine has greater potential to affect the gene pool of that species than loss of a population of red pine has to affect its gene pool. Management and land use activities can also affect genetic diversity. A comparison of genes of old-growth to second-growth red spruce (*Picea rubens*) populations in New Hampshire revealed that both had almost the same level of genetic diversity, but the old-growth stands had a very different array of **allozymes** (enzymes that vary with the allele that produced them), several unique to those stands (Soulé 1986). Genetic variation within populations of tree species is high relative to other plant taxa (Hamrick and Godt 1989).

The loss of genetic resources within populations can be detected by looking at the diversity and frequency distribution of allozymes (these enzymes are used to track genetic diversity), **microsatellites** (small portions of nuclear DNA), and **minisatellites** (slightly larger regions of DNA). These features, however, are not routinely tracked by managers. In lieu of laboratory measurements, the concept of effective population size is used to discuss and track how genetic variation is lost through time. **Effective population size** considers factors such as census population size, mating system, sex ratio of the species, variation in reproductive success, and interpopulation migration. Concern about genetic diversity is most serious for species with populations that are either naturally small and isolated or populations that have become small because of changes in their environment (Nei 1987, Nei and others 1975, Wright 1969).

Indicator 8. Number of forest-dependent species that occupy a small portion of their former range

The geographic area in which a given plant or animal normally lives is its **range.** A species is **endemic** within its natural range. If its range is limited to a small unique habitat, it may be referred to as a **local endemic species.** An **extirpated species** is a species that is no longer found in a portion of its former range. An **extinct** species is one that has disappeared from the earth. Twenty-five Northern United States species are presumed to be extinct or possibly extinct; of these six are birds, seven are fish, eight are freshwater mussels, and four are flowering plant species. The passenger pigeon (*Ectopistes migratorius*) became extinct in the early 1900s owing to unregulated hunting and habitat changes.

Most vertebrates endemic to the temperate region have broad geographic ranges and use a variety of habitats, although birds exhibit more habitat specificity than other vertebrates (DeGraaf and Miller 1996). Due to the effects of glaciation in much of the Northern United States, relatively few species are locally endemic. The Missouri Ozarks is one area where local endemic species are more common (Nigh and others 1992).

Species composition in Northern United States forests has fluctuated across the landscape since the time of European settlement as a result of habitat changes associated first with forest harvest and land clearing practices and then with reforestation (e.g., DeVos 1964, Martin and Klein 1984, Pielou 1991). Examples of wide-ranging forest-associated species found in the Northern United States include black bear, white-tailed deer (*Odocoileus*

virginianus), wild turkey (*Meleagris gallopavo*), ruffed grouse (*Bonsa umbellus*), mice and voles (family Muridae, subfamily Murinae and Signodontinae), numerous woodpeckers (family Picidae), thrushes (*Catharus* sp.), most wood warblers (family Parulidae), chickadees (*Poecile* sp.), titmice (*Baeolophus bicolor*), and raptors (Orders Falconiformes and Strigiformes).

Forest carnivores historically found and still found within forests of the Northern United States include large carnivores such as the gray wolf, red wolf (*Canis rufus*), coyote, wolverine (*Gulo gulo*), Canada lynx (*Lynx canadensis*) (Fuller and Kittredge 1996), and eastern cougar (*Felis concolor couguar*). Other carnivores include red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), and a variety of mustelid (e.g., pine marten [*Martes martes*], fisher [*Martes pennanati*], ermine [*Mustela erminea*], long-tailed weasel [*Mustela frenata*], least weasel [*Mustela nivalis*], mink [*Mustela vison*], otter [*Lutra canadensis*], badger [*Taxidea taxus*], and striped skunk [*Mephitis mephitis*]).

In New England, no forest mammals became extinct during the settlement period; however, elk (*Cervus elaphus*), woodland caribou (*Rangifer tarandus-caribou*), gray wolf, and eastern cougar were extirpated and have not recolonized their former territory.

In Wisconsin, unregulated commercial hunting and trapping and habitat change resulted in the extirpation of elk, wolverine, woodland caribou, and Canada lynx, which have not recolonized the State. Extirpated species that have reestablished include fisher, pine marten, and eastern timber wolf (*Canis lupus lycaon*). The eastern cougar and moose (*Alces alces*) were extirpated but now occur in very low numbers (Wisconsin Department of Natural Resources 1995).

Wolves historically were found throughout North America, but now are restricted to the northern United States and Canada. Road densities appear to be correlated with changes that affect their range. One study suggested that road densities greater than 0.6–0.7 km/km^2 affect the range of wolves (DeGraaf and Miller 1996). Coyotes are widely distributed today.

Indicator 9. Population levels of representative species from diverse habitats monitored across their range

Population trends for a variety of vertebrate species using habitats found within the Northern United States are discussed below. No scheme of representation of habitats has been attempted. Most vertebrates endemic to the temperate region have broad geographic ranges and use a variety of habitats (DeGraaf and Miller 1996). Many studies compare current populations to those present before or after European settlement, as a measure of the relative abundance of various species populations. Before European settlement of eastern North America, fauna were abundant and extinctions were few (Martin and Klein 1984, Pielou 1991).

Mammals that are found throughout their range today include gray squirrel (*Sciurus caroliniensis*), porcupine (*Erethizon dorsatum*), flying squirrel (*Glaucomys sabrinus*), and beaver (*Castor canadensis*). Those that increased include raccoon (*Procon totor*), striped skunk, woodchuck (*Marmota monax*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), and eastern cottontail (*Sylvilagus floridanus*).

After near extinction in the conterminous 48 States, the gray wolf is on the way to recovery. The population in the western Great Lakes States is increasing, with over 2,000 wolves in Minnesota, 180 in Wisconsin, and 140 in Michigan's Upper Peninsula (Mitchell 1998). The wolf population in Wisconsin prior to settlement has been estimated at 3,000 to 5,000 (Wydeven 1993). It is estimated that there were 5.8 deer/km^2 in disturbed forests of Wisconsin before European settlement (Mattfeld 1984). Today deer are abundant in many areas and pose a threat to forest regeneration. The black bear is an omnivore present in forested settings. Presettlement bear density in primeval deciduous forest in the East has been estimated between 19/100 km^2 (Shelford 1963) and 8/100 km^2. Bear density in western Massachusetts today is higher, about 30/100 km^2 (Fuller 1993).

Birds exhibit more habitat specificity than other vertebrates. Figure 1.17 depicts the proportion of bird species with increasing, decreasing, and stable populations from 1966 to 1996 in the Northern United States. Birds have been grouped by broad life history characteristics including nest type (cavity or open cup), nest location (ground, low, midstory, or canopy), and breeding habitat.

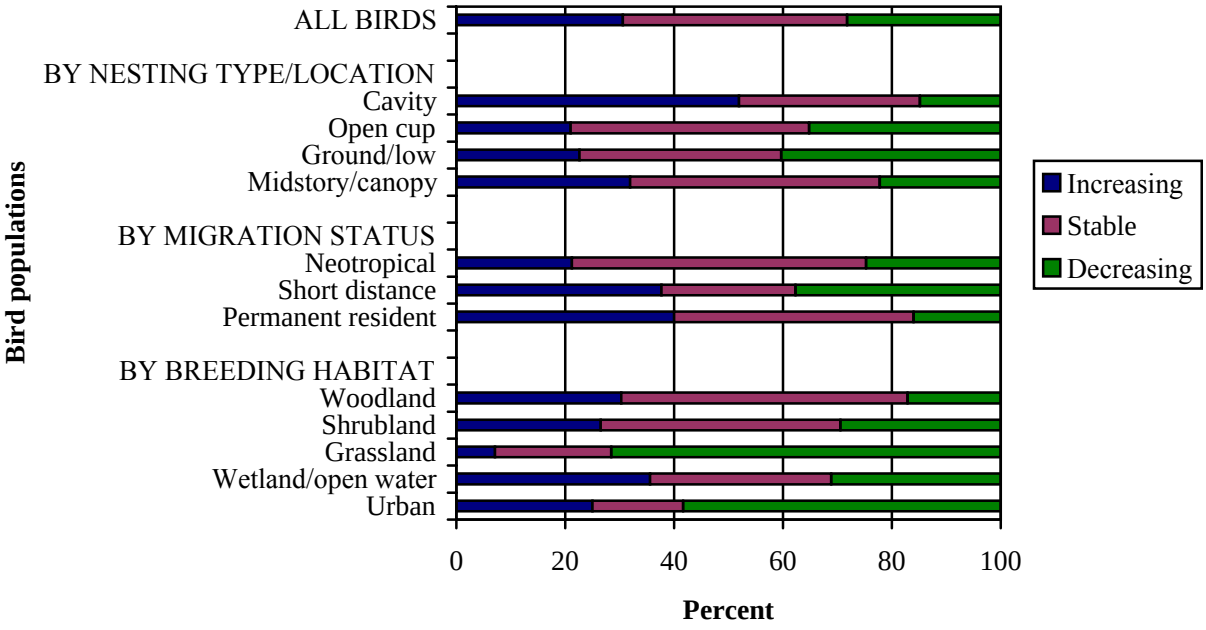


Figure 1.17. **Status of bird populations in the Northern United States**. Over 70 percent of bird species had stable or increasing populations between 1966 and 1996 (Flather and others 1999).

There are a variety of definitions for **Neotropical migratory bird species**. In DeGraaf and Rappole (1995), they are defined as "Western Hemisphere species that breed north of the Tropic of Cancer and winter south of that line" (p. 9). The researchers identified 361 species of Neotropical migrants representing 38 families of birds breeding in the United States and Canada. The family containing the most species is Emberizidae (wood-warblers, tanagers, orioles, and sparrows), which includes 95 species and more than 25 percent of all Neotropical migrants.

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 (figure 1.18). Some Neotropical migratory birds, especially species that are primary forest specialists on the wintering grounds (e.g., wood thrush [*Hylocichla mustelina*] and cerulean warbler [*Dendroica cerulea*]), are declining in some parts of their breeding ranges owing largely to events on the wintering grounds or during migration (DeGraaf and Rappole 1995, Hagan and Johnston 1992, Robbins and others 1992, Terborgh 1989).

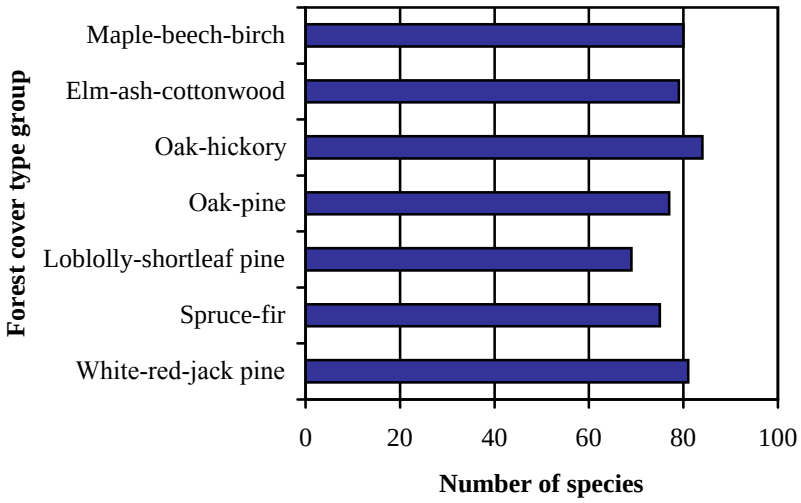


Figure 1.18. **Numbers of Neotropical migrant species breeding in forest cover type groups found in the Northern United States**. Most species breed in more than one forest type group (adapted from DeGraaf and Rappole 1995).

Population trends for waterfowl associated with forested wetlands are complex (Erwin 1996). Wood duck (*Aix sponsa*) populations have generally increased in the United States. The Canada goose (*Branta canadensis*), which feeds occasionally in forested wetlands and agricultural fields, has increased in recent years. There have been midcontinental declines in northern pintail (*Anas acuta*), Mississippi Flyway populations of mallard (*Anas platyrhynchos*), and green-winged teal (*Anas creca*). The black duck (*Anas rubripes*) has declined despite stable or increasing forest area in maritime Canada and New England. Blue-winged teal (*Anas discors*) has also declined in the United States. Common mergansers (*Mergus merganser*) and hooded mergansers (*Lophodytes cucullatus*), which feed in wetlands in the northern tier of States, have increased nationally.

In New England, the decline of agriculture and reversion to forest has essentially eliminated grassland birds. Resident forest birds have increased in abundance in extensive woodlands. The pileated woodpecker (*Dryocopus pileatus*), which requires large trees for nest and roost cavities, has increased in the last 25 years (Bull 1975, Norse 1985). The wild turkey has been restored from wild stock throughout its former range (Kennamer and Kennamer 1990).

Nationwide population levels for large carnivores increased between 1975 and 1990. Black bear increased 60 percent overall. Population levels for herbivores generally increased with localized declines for some species in some regions. Harvest estimates for small game mammals with small home ranges generally declined. Harvests of game birds show mixed trends (USDA Forest Service 1997).

Conservation of Genetic Diversity

It is desirable to preserve genetic diversity through the protection of viable populations **in situ,** that is, in a natural setting, rather than **ex situ**, in a laboratory or other site outside a natural habitat. This is especially true of wildlife species, for which the difficulty and costs of ex situ conservation can be very high. The only Federal land protection program with a direct mandate for in situ genetic diversity conservation is the USDA Forest Service Research Natural Areas Program. Conservation of genetic diversity is a factor considered by the U.S. Fish and Wildlife Service in the development of in situ conservation and recovery plans for threatened and endangered species.

Nongovernment institutions and organizations may also become involved in conservation of genetic diversity. For example, since the 1970s, members of the American Zoo and Aquarium Association have become actively involved in conservation programs for imperiled species. They cooperate with U.S. Fish and Wildlife Service species recovery efforts by working toward the maintenance of healthy, self-sustaining captive populations that are genetically diverse, and they invest in research to develop species-specific information to promote advancements in captive propagation and reintroduction technologies.

Wildlife population management can affect genetic diversity. Animal populations have the potential to lose genetic variation at a much faster rate than plant populations. This is a result of the social structure often associated with animals and their ability to choose with whom they mate. Genetic variation is lost at a faster rate when one animal dominates the mating opportunities (e.g., elk, elephant, seals), when the social structure is such that the mating individuals are more closely related than average, or if the few breeders are closely related—even if the animals they mate with are not related.

The integration of population genetics and wildlife management opens doors into a broader and more accurate understanding of managed populations. Genetic mark-recapture allows researchers to refine population estimates by decreasing double-counting of individuals. Recent advances allow quantification of current rates of dispersal between populations based on molecular genetics and examination of the recent demographic history of a population to determine if demographics have affected genetic characteristics (Swanson, Bradley. 2000. Personal communication. Wildlife geneticist, University of Wisconsin–Stevens Point.)

Most forestry and wildlife habitat management in the Northern United States depends on wild plants growing in naturally regenerated stands. Silviculturists prescribe treatments in naturally regenerating stands that favor the most vigorous individuals according to the demands of the locale. They try to establish stands with traits that increase their desirability for timber and wildlife. Sustainable management ensures that trees that remain after harvest as breeding stock 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 that produces individuals with undesirable traits.

Crop and tree breeding programs are forms of genetic resource management that have had direct benefits to humankind in increased growth and yield. Hybrid species are developed to increase resistance to insects and disease or to increase productivity under specific

environmental conditions. The use of hybrids in plantations raises some questions related to the preservation of genetic integrity.

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, or restoration activities. They are often framed as minimum number of parental trees to be included in seed orchards, minimum number of clones per breeding population, maximum number of related families to be used within a planting unit, and maximum amount of land that can be reforested with individual families within a specific timeframe. 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 and with other beneficial attributes (Garrett and others 1973, Santamour 1960, Sluder 1963).

Maintaining genetic diversity involves protecting genetic integrity and maintaining genes of native stock (Rogers and Thomas 1996). For foresters this is a management consideration associated with tree nurseries and the use of hybrids and exotic species. The number of private nurseries is unknown. Although actual species production information has not been collected in a while, there has been general movement away from production of exotics by public nurseries since 1990 or so. Exceptions are nurseries that grow primarily Christmas tree stock. In the Northern United States, 15 States have State nursery programs and 21 have State nurseries.

Summary and Conclusions

In the Northern United States, forest land was more extensive at the time of European settlement than it is today. It is unlikely that the total forested acreage will reach those historical levels again owing to trends in urban and suburban development. No natural communities are known to have been eliminated since European settlement; however, the cumulative impacts of land drainage, conversion to agriculture, fire suppression, land tract parcelization, and urban development have affected landscape patterns, plant and animal species distributions, and population levels. If current management continues, acreage of mature forest in the Northern United States will increase, probably of the maple-beech-birch and oak-hickory cover types, and acreage of the aspen-birch cover type will decrease. Old-growth forest acreage accounts for, at most, less than 2 percent of forest land.

Assessments of species at risk are incomplete, but so far, most native plants and animals evaluated in the Northern United States are doing well, while a tenth are not doing well. Twenty-five Northern U.S. species are presumed to be extinct. Population levels and the distribution of forest-dependent species have fluctuated in the past owing to conversion of land from forest to agriculture and subsequent reforestation. A variety of species that were once widespread, such as wolf and lynx, are restricted to a portion of their former ranges owing to human encroachment. The greatest threat to forest-dependent species now is the permanent loss of forest land habitat to urban and suburban development. Species requiring extensive areas of unbroken forest land are in decline. Neotropical migratory species are in decline. Aquatic species are especially stressed. Various exotic species of plants and animals are competing with native plants and animals or degrading forest habitat.

Public land plays a key role in biodiversity conservation; however, the large amount of private land in the Northern United States means conservation efforts must include effective private land strategies. Information on private forest land conservation is limited.

Appendix 1–A. Amount of forested and nonforested land within provinces of the Northern United States

Province	Forest	Nonforest	Total
		Thousand acres	
212	62,574.9	25,529.0	88,103.8
M212[1]	23,083.9	2,561.4	25,645.3
221	24,666.2	21,385.6	46,051.9
M221	14,487.0	6,132.8	20,619.7
222N	17,942.2	74,146.6	92,088.8
222S	16,968.0	25,607.9	42,575.8
231	73.5	210.4	283.9
232	3,387.7	4,836.7	8,224.4
234	169.2	2,383.6	2,552.8
251	6,069.1	79,766.4	85,835.5
Total	**169,421.7**	**242,560.4**	**411,982.1**

[1]Includes 2,594,600 acres of Adirondack and Catskill Preserves (NY) not tallied in data source.
Source: USDA Forest Service 1999b.
Inventory follows methods in Hansen and others (1992).

Appendix 1–B. Scientific names of species referenced in forest cover types (see table 1.2)

American elm (*Ulmus americana*)
Ash (*Fraxinus* spp.)
Aspen (*Populus* spp.)
Atlantic white cedar (*Chamaecyparis thyoides*)
Baldcypress (*Taxodium distichum*)
Balsam fir (*Abies balsamea*)
Balsam poplar (*Populus balsamifera*)
Basswood (*Tilia americana*)
Beech (*Fagus* spp.)
Black ash (*Fraxinus nigra*)
Black cherry (*Prunus serotina*)
Black locust (*Robinia pseudoacacia*)
Black oak (*Quercus velutina*)
Black spruce (*Picea mariana*)
Black walnut (*Juglans nigra*)
Blackjack oak (*Quercus marilandica*)
Cherry (*Prunus* spp.)
Cherrybark oak (*Quercus pagoda*)
Chestnut oak (*Quercus prinus*)
Cottonwood (*Populus* spp.)
Eastern redcedar (*Juniperus virginiana*)
Elm (*Ulmus* spp.)
Gray birch (*Betula populifolia*)
Green ash (*Fraxinus pennsylvanica*)
Hackberry (*Celtis* spp.)
Hemlock (*Tsuga* spp.)
Hickory (*Carya* spp.)
Jack pine (*Pinus banksiana*)
Loblolly pine (*Pinus taeda*)
Locust (*Robinia* spp.)
Northern red oak (*Quercus rubra*)
Northern white cedar (*Thuja occidentalis*)
Nuttall oak (*Quercus texana*)
Oak (*Quercus* spp.)
Overcup oak (*Quercus lyrata*)
Paper birch (*Betula papyrifera*)
Pecan (*Carya illinoinensis*)
Persimmon (*Diospyros virginiana*)
Pine (*Pinus* spp.)
Pitch pine (*Pinus rigida*)
Pond pine (*Pinus serotina*)
Post oak (*Quercus stellata*)
Red maple (*Acer rubra*)
Red oak (*Quercus rubra*)
Red pine (*Pinus resinosa*)
Red spruce (*Picea rubens*)
River birch (*Betula nigra*)
Sassafras (*Sassafras albidum*)
Scarlet oak (*Quercus coccinea*)
Shortleaf pine (*Pinus echinata*)
Silver maple (*Acer saccharinum*)
Southern red oak (*Quercus falcata*)
Sugar maple (*Acer saccharum*)
Sugarberry (*Celtis laevigata*)
Swamp chestnut oak (*Quercus michauxii*)
Swamp tupelo (*Nyssa biflora*)
Sweetbay (*Magnolia virginiana*)
Sweetgum (*Liquidambar styraciflua*)
Sycamore (*Platanus occidentalis*)
Table-mountain pine (*Pinus pungens*)
Tamarack (eastern larch) (*Larix laricina*)
Virginia pine (*Pinus virginiana*)
Water hickory (*Carya aquatica*)
Water tupelo (*Nyssa aquatica*)
White ash (*Fraxinus americana*)
White oak (*Quercus alba*)
White pine (*Pinus strobus*)
White spruce (*Picea glauca*)
Willow (*Salix* spp.)
Willow oak (*Quercus phellos*)
Yellow birch (*Betula alleghaniensis*)
Yellow-poplar (*Liriodendron tulipifera*)

Appendix 1–C. Example of U.S. Natural Vegetation Classification association description

Pinus resinosa/*Vaccinium* spp. Forest

Red Pine/Blueberry Dry Forest (CEGL002443)

Description: This community is characterized by a pine overstory and a poorly developed understory. *Pinus resinosa* is present in the canopy at a higher cover and basal area than other conifers (typically 80% or more). *P. strobus* can be common in the canopy. Mesic sites tend to include not only *P. resinosa*, but *Picea mariana*, *Picea glauca*, and *Abies balsamea* in the canopy, while on dry sites, *P. banksiana* is found (MN NHP 1993). Beneath the canopy, northern hardwoods such as *Acer rubrum* and *Betula papyrifera* sometimes form a subcanopy. The understory ranges from moderately herb and shrub rich to extremely poor. In the tall shrub class, the important species are *Amelanchier* spp. and *Corylus cornuta*. The short shrub layer includes *Gaultheria procumbens*, *Linnaea borealis*, *Vaccinium angustifolium*, and *Vaccinium myrtilloides*, particularly where gaps in the canopy occur (Ohmann and Ream 1971). The herb layer is very poorly represented in most parts of this community's range, and includes *Aralia nudicaulis*, *Aster macrophyllus*, *Cornus canadensis*, *Maianthemum canadense*, *Pteridium aquilinum*, and *Trientalis borealis*. Mosses can have very high cover, and typically include *Dicranum* spp. (including *Dicranum polysetum*) and *Pleurozium schreberi*. The average coverage of feathermoss was greater in the northwest region of Ontario than in the northcentral region (Sims *et al.* 1989).

This community occurs on Precambrian bedrock, overlaid with medium deep (> 60 cm), coarse sand or coarse loam soils. Moisture varies from dry to dry-mesic, and stands are on mid to upper gentle slopes. The climate is highly variable, with temperature extremes between -46 ˚C and 38 ˚C, and anywhere from 58–91 cm of precipitation.

Fire is an important natural disturbance in this community. *P. resinosa* has adaptations that make it well suited to frequent ground fires and occasional crown fires. Reconstructions of the fire regime (Heinselman 1973, Frelich 1992) in red and white pine stands indicate that a combination of ground fires every 20 to 30 years, and severe crown fires every 100–150 years maintained presettlement *P. resinosa* communities. The thick, corky bark of older *P. resinosa* make them more resistant to fire than any other type of pine. The stems of older *P. resinosa* are likely to have better survival rates than *P. strobus* and *P. banksiana* when no crown damage results (Ahlgren 1974). In addition *P. resinosa* seedling establishment is favored by exposed mineral soils and high sunlight. Therefore relatively frequent fires makes the continued regeneration of *P. resinosa* possible, as they are only moderately shade tolerant. Fire suppression over much of the *P. resinosa* range appears to be leading towards the gradual succession from *P. resinosa* forests to forests of mesic hardwoods or *P. strobus*, species that, with a frequent fire regime, are confined to the understory (MN NHP 1993).

Classification Comments: *1, MCS*. This community can inter-grade with *Pinus strobus* dominated forests. Red pine stands in the central Great Lakes region, often on sandy outwash, are treated with more boreal stands as one type, since the ericaceous component is similar. It remains to be seen whether the central stands may sufficient enough common boreal elements of the more northern stands to warrant a separate type.

Appendix 1–C. Example of U.S. Natural Vegetation Classification association description (cont.)

Global Conservation Rank: *G3*. There are probably over 100 occurrences of this community rangewide. Currently there are 77 occurrences documented from Michigan (where it is ranked S3), Minnesota (S3), and Wisconsin (S3); it is also reported from Manitoba (S3) and Ontario (S?).[1] There are probably over 10,000 acres of this community rangewide. Currently 5,545 acres have been documented from 45 occurrences in Michigan, Minnesota, and Wisconsin. Some sites have been degraded by logging, but there are also many mature to old-growth stands remaining.

Distribution: This upland red pine community type is found in the northern Great Lakes and parts of central Canada.

USFS Ecoregions: 212H:C, 212I:C, 212J:C, 212K:C, 212L:C, 212M:C, 212N:C, 222M:C
Conservation Regions: 46:C, 47:C, 48:C

States: MI, S3, dry northern forest +| MN, S3, red pine forest =| WI, S3, S3, northern dry forest, red pine subtype =
Provinces: MB, S1, Pinus resinosa/Vaccinium spp. Forest| ON, S?, Dry – Fresh White Pine – Red Pine Coniferous Forest Type +

Synonymy: Red Pine = (Ohmann and Ream 1971)| Red Pine Conifer (V27) (Sims et al. 1989)| Red Pine-White Pine-Jack Pine-Blueberry-Feathermoss (V30) – (Chambers 1997)| Red Pine-White Pine-Jack Pine-Largetooth Aspen-White Pine Shrub-Wintergreen (V31) – (Chambers 1997)

[1]Definitions of State rankings (S3 and S?) match those of the global rankings listed in appendix 1–D.
Source: excerpt from Faber-Langendoen 1999, p. 362-363.

Appendix 1–D. Global conservation status ranks for community elements[1]

Global rank	Definition
GX	**Eliminated**: Eliminated throughout its range, with no restoration potential owing to extinction of dominant or characteristic species.
GH	**Presumed eliminated (historic)**: Presumed eliminated through its range with little likelihood of being rediscovered, but with the potential for restoration.
G1	**Critically imperiled**: Generally 5 or fewer occurrences and/or very few remaining acres or very vulnerable to elimination throughout its range because of other factors.
G2	**Imperiled**: Generally 6–20 occurrences or few remaining acres or very vulnerable to elimination throughout its range owing to other factors.
G3	**Vulnerable**: Generally 21–100 occurrences. Either very rare and local throughout its range; found locally, even abundantly, with a restricted range; or vulnerable to elimination throughout its range owing to specific factors.
G4	**Apparently secure**: Common, widespread and abundant (though it may be quite rare in parts of its range, especially at the periphery). Apparently not vulnerable in most of its range.
G5	**Secure**: Common, widespread, and abundant (although it may be quite rare in parts of its range, especially at the periphery). Not vulnerable in most of its range.
GU	**Unrankable**: Status cannot be determined at the time.
G?	**Unranked**: Status has not yet been assessed.

[1]Global conservation status ranks and definitions developed by the Natural Heritage Network and The Nature Conservancy (adapted from Grossman and others 1998).

Appendix 1–E. Globally rare forest and woodland associations by province

Class/subclass: common name	Province distribution[1]
Forest/evergreen:	
Maritime Holly Forest	232
Great Lakes Dune Pine Forest	212, 222
Shortleaf Pine/Blueberry Forest	221, 222, 231, M222, M231, M221
Red Pine/Blueberry Dry Forest	212, 222
White Pine-(Red Pine) Driftless Bluff Forest	222
White Pine Inland Dune Ridge Forest	212
Great Lakes White Pine-Hemlock Forest	212, 222?
White Pine/Mountain Maple Mesic Forest	212
White Pine/Blueberry Dry-Mesic Forest	212, 222, M212
Coastal Loblolly Pine Forest	232
Red Spruce-Fraser Fir Forest (Hemlock type)	M221
Red Spruce Forest (Protected Slope type)	M221
White Cedar-(Hemlock) Mesic Forest	212
Hemlock Mesic Forest	212, 222
Hemlock Relict Forest	222
Boreal Atlantic White Cedar Swamp	221
Coastal Plain Atlantic White Cedar Swamp	221, 232
Inland Atlantic White Cedar Swamp	221, M212
Peatland Atlantic White Cedar Forest	232
Swamp Forest-Bog Complex (Spruce type)	212, M221
Coastal Loblolly Pine Wetland Forest	232
White Cedar Seepage Swamp	212, 222
Hemlock-Yellow Birch Wet-Mesic Forest	212, 221, 222
Forest/deciduous:	
Central Maple-Basswood Forest	222, 251
Maple-Yellow Birch Northern Hardwoods Forest	212
Sugar Maple-Oak-Bitternut Hickory Mesic Bottomland Forest	222, M222, M231
Northern Maple-Basswood Forest	212
Beech-Maple-Sweetgum Sand Forest	234
Beech-Hardwoods Till Plain Flatwoods	222
Beech-Maple Glaciated Forest	212, 221, 222, 251
Beech-Oak-Red Maple Flatwoods	222, 234
Maritime Beech Forest	221, 232
White Oak-Hickory Forest	222, 251
White Oak-Maple Mesic Forest	222, 231, 251
Midwest Oak-Maple Mesic Sand Forest	251?
Blackjack Oak Xeric Scrub	222, 231, M231

[1] ? = association expected to occur in province, but not confirmed
Source: TNC and ABI 2000.

Appendix 1–E. Globally rare forest and woodland associations by province (cont.)

Class/subclass: common name	Province distribution[1]
Forest/deciduous (cont.):	
Post Oak Flatwoods	222, 231?, 234, 251
Bur Oak-Basswood Forest	251, 332
Southern Appalachian Boulderfield Forest (Currant and Rockcap Fern type)	M221
Silver Maple-Sugarberry-Pecan Terrace Forest	222, 231, 234, 251
Maple-Hickory Floodplain Ridge and Terrace Forest	222, 251
Beech-Mixed Hardwood Floodplain Forest	221, 222
Northern Ash-Elm-Hackberry Floodplain Forest	212, 222, 251
Sycamore-Silver Maple Floodplain Forest	221, 222, 231, M221
Cottonwood-Black Willow Forest	222, 231, 232, 234, 251
Bur Oak-Swamp White Oak Mixed Bottomland Forest	222, 251
Swamp Chestnut Oak-Sweetgum Mesic Floodplain Forest	222, 231, 232, 234
Central Coastal Plain Basin Swamp	232
Overcup Oak-Nuttall's Oak Bottomland Forest	222, 234
Pin Oak-Swamp White Oak Forested Acid Seep	222, 234, M222
Pin Oak-Post Oak Lowland Flatwoods	222, 231, 234
Northern (Great Lakes) Flatwoods	221, 222
Pin Oak-Swamp White Oak Sand Flatwoods	222, 251, 232
Water Tupelo Sinkhole Pond Swamp	222, 234
Red Maple Forested Fen	222, M221?
Cape May Lowland Swamp	232
Southern Red Maple-Black Gum Swamp Forest	232
Interior Forested Acid Seep	222
Central Appalachian Circumneutral Seepage Swamp	M212, M221
Central Tamarack-Red Maple Rich Swamp	221, 222
Forest/mixed evergreen-deciduous:	
Shortleaf Pine-Black Oak Forest	222, 231, M221?, M222, M231
White Pine-Red Oak Forest	212, 222
Driftless White Pine-Northern Hardwoods Forest	222
White Pine-Oak Morainal Ridge Forest	212
White Pine-White Oak Forest	212, 222
Eastern White Cedar-Yellow Birch Forest	212
East-Central Hemlock Hardwood Forest	212, 221, 222
Delmarva Atlantic White Cedar Swamp	232
White Pine-Red Maple Swamp	212, 221, 222

[1] ? = association expected to occur in province, but not confirmed
Source: TNC and ABI 2000.

Appendix 1–E. Globally rare forest and woodland associations by province (cont.)

Class/subclass: common name	Province distribution[1]
Woodland:	
Central Appalachian Table Mountain Pine-Pitch Pine-Heath Woodland	222, M221
Jack Pine-Red Pine/Scrub Oak Woodland	212
Shortleaf Pine/Little Bluestem Woodland	222, 231, M222
Midsuccessional Pine-Oak Woodland	232
Coastal Pitch Pine Outcrop Woodland	212
Pitch Pine Dune Woodland	212, 221, 232
New Jersey Pitch Pine/Scrub Oak Barren	232
New Jersey Mesic Pine Barrens	232
Inland Pitch Pine/Scrub Oak Barren	221
Coastal Pitch Pine/Scrub Oak Barren	221, 232
Northern Pitch Pine/Scrub Oak Barren	221, 232
Traprock Ridge	212
Limestone Woodland	221
Red Cedar Rocky Summit	222
Maritime Redcedar Woodland	221, 232, 231, M221
Appalachian Bluff White Cedar Woodland	222
White Cedar Bluff Woodland	212, 222
White Cedar Limestone Bedrock Woodland	212
White Cedar Limestone Talus Woodland	212, 232, 221, 232, 221
Swamp Forest-Bog Complex (Long Hope Valley Woodland type)	M221
Mesic Pine Barrens	212, 221
Pitch Pine Lowland; Pitch Pine-Pineland Reedgrass Savanna	232
Pitch Pine Lowland	232, 212, 221
Sugar Maple-Oak-Hickory Limestone Woodland	212, 221, 222, M221
Kentucky Red-Cedar-Blue Ash Woodland	221?, 222
White Oak Central Glaciated Woodland	251
Northern Dry-Mesic Oak Woodland	212, 222, 251
White Oak-Post Oak/Bluestem Woodland	222, 231, 251?, M222
Lake Plain Mesic Oak Woodland	222
Swamp White Oak Woodland	251
Bur Oak Terrace Woodland	212?, 222, 251
Bur Oak-Chinquapin Oak Woodland	251
Eastern Great Plains Bur Oak Woodland	251, 332
Bur Oak/Hazelnut Woodland	251, 331
Limestone Woodland	212?, 221?, M212, M221
Oak Openings	222, M221, 221

[1] ? = association expected to occur in province, but not confirmed
Source: TNC and ABI 2000.

Appendix 1–E. Globally rare forest and woodland associations by province (cont.)

Class/subclass: common name	Province distribution[1]
Woodland (cont.):	
Post Oak-Blackjack Oak/Little Bluestem Woodland	222, 231, M222, M231
Post Oak-Blackjack Oak/Bluestem Sand Woodland	222, 234
Post Oak-Mixed Oak Sand Woodland	222, 234
Post Oak Clay Barrens	222
Cottonwood Floodplain Woodland	222?, 251
Delmarva Tidal Swamp	232, 221, 232
Shortleaf Pine-Oak Dry-Mesic Woodland	222, 231, M221
Shortleaf Pine-Oak Dry Woodland	222, 231, M222, M231, M221
Dry Riverbluff Opening Community	221
White Pine-White Oak Sand Woodland	212, M221, 221

[1] ? = association expected to occur in province, but not confirmed
Source: TNC and ABI 2000.

Appendix 1–F. Change in land cover/use[1] from 1982 to 1997 in the Northern United States

Land cover/use in 1982	Land cover/use in 1997								1982 total
	Other	Crop-land	Pasture-land	Range-land	Forest land	Urban	Water	CRP land	
	Thousand acres								
Other	**11,765**	711	443	0	1,658	240	9	40	**14,866**
Cropland	1,216	**135,450**	5,933	0	1,519	3,080	263	6,776	**154,236**
Pastureland	727	7,630	**29,226**	0	6,485	1,205	138	641	**46,051**
Rangeland	0	12	21	**86**	25	0	0	0	**143**
Forest land	731	722	1,037	2	**145,192**	3,710	527	35	**151,956**
Urban	4	104	33	0	96	**28,635**	0	1	**28,874**
Water	5	143	44	0	180	3	**29,959**	2	**30,336**
1997 total	**14,448**	**144,772**	**36,737**	**88**	**155,156**	**36,873**	**30,896**	**7,494**	**426,462**

[1]The 1982 land cover/use totals are listed in the right-hand vertical column, titled "1982 total." The 1997 land cover/use totals are listed in the bottom horizontal row, titled "1997 total." The number at the intersection of rows and columns with the same land cover/use designation represents acres that did not change from 1982 to 1997. Reading to the right or left of this number are the acres that were lost to another cover/use by 1997. Reading up or down from this number are the acres that were gained from another cover/use by 1997. Standard errors of the estimates are available from USDA NRCS.

Cropland—comprises cultivated cropland in row crops or close-grown crops and other cultivated cropland, for example, hay land that is in a rotation with row or close-grown crops.
Pastureland—land managed primarily for the production of introduced forage plants for livestock grazing.
Rangeland—land on which the climax or potential cover is primarily native grasses, grasslike plants, forbs, or shrubs suitable for grazing and browsing, and introduced forages species that are managed like rangeland.
Forest land—land that is at least 10 percent stocked by single-stemmed woody species of any size that will be at least 4 meters tall at maturity. Also included is land bearing evidence of natural regeneration of tree cover and not currently developed for nonforest use.
Urban—consists of residential, industrial, commercial, and institutional land.
Water—consists of permanent water, such as a perennial stream, lake, or pond with at least 25 percent open water.
CRP land—includes land under a Conservation Reserve Program (CRP) contract, a Federal program established under the Food Security Act of 1985 to assist private landowners to convert highly erodible cropland to vegetative cover for 10 years.

Source: USDA NRCS 2000.

Appendix 1–G. Total forest land and forest land converted to urban land from 1982 to 1997 in the Northern United States

State	Forest land		Forest land converted to urban land
	1982	1997	
	Thousand acres		
Connecticut	1,823	1,759	101
Delaware	370	352	19
Illinois	3,585	3,784	68
Indiana	3,779	3,781	93
Iowa	1,860	2,182	15
Maine	17,640	17,691	154
Maryland	2,458	2,373	148
Massachusetts	3,070	2,744	368
Michigan	15,816	16,354	373
Minnesota	15,980	16,248	148
Missouri	11,456	12,431	168
New Hampshire	4,128	3,932	181
New Jersey	1,900	1,698	273
New York	16,738	17,702	287
Ohio	6,658	7,081	286
Pennsylvania	15,508	15,478	621
Rhode Island	401	387	23
Vermont	4,157	4,150	51
West Virginia	10,413	10,582	190
Wisconsin	14,215	14,448	145
Total	**151,956**	**155,156**	**3,710**

Note: Standard errors of the estimates are available from USDA NRCS.
Source: USDA NRCS 2000.

Appendix 1–H. Change in land cover/use[1] from 1982 to 1997 in the Northern United States by State

Connecticut

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**87**	2	3	22	2	0	0	**116**
Cropland	7	**180**	28	14	16	0	0	**245**
Pastureland	0	16	**76**	22	9	1	0	**124**
Forest land	9	5	5	**1,696**	101	5	0	**1,823**
Urban	0	0	0	4	**746**	0	0	**751**
Water	0	0	0	1	0	**136**	0	**137**
1997 total	**103**	**204**	**112**	**1,759**	**874**	**143**	**0**	**3,195**

Delaware

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**120**	1	1	1	0	0	0	**123**
Cropland	6	**464**	7	3	37	1	1	**519**
Pastureland	1	15	**15**	1	4	0	0	**35**
Forest land	1	4	1	**346**	19	0	0	**370**
Urban	0	0	0	0	**166**	0	0	**167**
Water	0	0	0	0	0	**319**	0	**319**
1997 total	**128**	**485**	**24**	**352**	**226**	**320**	**1**	**1,534**

Illinois

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**527**	62	27	17	21	0	2	**657**
Cropland	80	**23,287**	249	75	367	31	637	**24,726**
Pastureland	23	520	**2,166**	328	77	12	78	**3,204**
Forest land	22	77	47	**3,343**	68	21	7	**3,585**
Urban	1	30	3	7	**2,648**	0	0	**2,689**
Water	0	35	10	14	0	**1,139**	2	**1,198**
1997 total	**652**	**24,011**	**2,502**	**3,784**	**3,181**	**1,202**	**726**	**36,059**

[1] See footnote on page 75.

Appendix 1–H. Change in land cover/use[1] from 1982 to 1997 in the Northern United States by State (cont.)

Indiana

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**576**	69	37	43	18	0	1	**744**
Cropland	67	**12,693**	377	34	268	14	329	**13,780**
Pastureland	12	575	**1,388**	112	61	3	48	**2,200**
Forest land	18	53	25	**3,583**	93	8	0	**3,779**
Urban	0	7	2	5	**1,821**	0	0	**1,835**
Water	0	11	2	4	0	**804**	0	**820**
1997 total	**674**	**13,407**	**1,830**	**3,781**	**2,260**	**829**	**378**	**23,158**

Iowa

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**781**	96	34	7	4	0	6	**928**
Cropland	72	**24,119**	502	42	101	41	1,564	**26,440**
Pastureland	13	1,040	**3,006**	349	29	7	165	**4,609**
Forest land	4	26	25	**1,781**	15	5	5	**1,860**
Urban	0	22	5	2	**1,553**	0	0	**1,582**
Water	0	7	1	1	0	**589**	0	**598**
1997 total	**870**	**25,310**	**3,572**	**2,182**	**1,702**	**641**	**1,739**	**36,017**

Maine

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**435**	2	0	168	5	1	0	**610**
Cropland	19	**361**	36	60	32	1	13	**521**
Pastureland	15	48	**86**	78	16	10	12	**265**
Forest land	68	2	1	**17,375**	154	33	5	**17,640**
Urban	0	0	0	5	**505**	0	0	**510**
Water	0	0	0	6	0	**1,415**	0	**1,421**
1997 total	**537**	**413**	**123**	**17,691**	**712**	**1,460**	**30**	**20,966**

[1] See footnote on page 75.

Appendix 1–H. Change in land cover/use[1] from 1982 to 1997 in the Northern United States by State (cont.)

Maryland

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**301**	5	16	20	4	1	0	**347**
Cropland	10	**1,527**	91	32	113	7	15	**1,795**
Pastureland	4	61	**355**	59	60	3	4	**545**
Forest land	7	22	16	**2,261**	148	5	0	**2,458**
Urban	0	1	0	1	**911**	0	0	**913**
Water	0	1	0	2	0	**1,810**	0	**1,813**
1997 total	**321**	**1,616**	**478**	**2,373**	**1,236**	**1,826**	**19**	**7,870**

Massachusetts

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**217**	9	5	38	14	0	0	**284**
Cropland	7	**224**	7	19	39	1	0	**298**
Pastureland	5	22	**99**	37	26	0	0	**188**
Forest land	25	21	8	**2,642**	368	7	0	**3,070**
Urban	0	0	0	2	**1,032**	0	0	**1,034**
Water	0	1	0	7	0	**458**	0	**466**
1997 total	**254**	**277**	**119**	**2,744**	**1,479**	**466**	**0**	**5,339**

Michigan

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**1,714**	60	37	326	26	3	2	**2,168**
Cropland	240	**7,866**	568	175	280	10	305	**9,443**
Pastureland	160	541	**1,358**	658	161	10	15	**2,902**
Forest land	64	58	65	**15,172**	373	84	0	**15,816**
Urban	1	7	3	10	**2,706**	0	0	**2,725**
Water	0	9	2	13	0	**4,271**	0	**4,294**
1997 total	**2,178**	**8,540**	**2,032**	**16,354**	**3,546**	**4,378**	**321**	**37,349**

[1] See footnote on page 75.

Appendix 1–H. Change in land cover/use[1] from 1982 to 1997 in the Northern United States by State (cont.)

Minnesota

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Crop-land	Pasture-land	Forest land	Urban	Water	CRP land	
	Thousand acres							
Other	**2,452**	116	91	265	22	1	16	**2,962**
Cropland	120	**20,372**	752	63	229	47	1,442	**23,025**
Pastureland	92	823	**2,475**	300	92	15	76	**3,873**
Forest land	52	71	107	**15,555**	148	38	10	**15,980**
Urban	0	11	4	9	**1,696**	0	0	**1,720**
Water	0	21	6	57	0	**6,367**	0	**6,451**
1997 total	**2,716**	**21,414**	**3,434**	**16,248**	**2,186**	**6,468**	**1,544**	**54,010**

Missouri

Land cover/use in 1982	Land cover/use in 1997								1982 total
	Other	Crop-land	Pasture-land	Forest land	Urban	Water	CRP land	Range-land	
	Thousand acres								
Other	**499**	38	46	74	11	0	7	0	**675**
Cropland	47	**11,708**	1,523	118	133	49	1,423	0	**15,000**
Pastureland	53	1,892	**8,863**	1,414	142	38	170	0	**12,573**
Forest land	34	70	374	**10,763**	168	41	6	2	**11,456**
Urban	0	5	8	7	**2,064**	0	0	0	**2,084**
Water	1	27	14	30	0	**2,611**	0	0	**2,682**
Rangeland	0	12	21	25	0	0	0	86	**143**
1997 total	**634**	**13,751**	**10,849**	**12,431**	**2,517**	**2,738**	**1,606**	**88**	**44,614**

New Hampshire

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Crop-land	Pasture-land	Forest land	Urban	Water	CRP land	
	Thousand acres							
Other	**153**	1	2	28	5	0	0	**188**
Cropland	7	**122**	5	3	20	0	0	**158**
Pastureland	6	8	**80**	18	5	2	0	**119**
Forest land	27	3	7	**3,882**	181	30	0	**4,128**
Urban	0	0	0	1	**378**	0	0	**379**
Water	0	0	0	1	0	**968**	0	**969**
1997 total	**193**	**134**	**94**	**3,932**	**589**	**999**	**0**	**5,941**

[1] See footnote on page 75.

Appendix 1–H. Change in land cover/use[1] from 1982 to 1997 in the Northern United States by State (cont.)

New Jersey

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**324**	6	1	20	25	0	0	**375**
Cropland	16	**528**	26	56	177	5	0	**809**
Pastureland	12	37	**81**	43	41	2	1	**216**
Forest land	15	16	3	**1,574**	273	19	0	**1,900**
Urban	0	1	0	2	**1,262**	0	0	**1,266**
Water	0	1	0	4	0	**645**	0	**650**
1997 total	**367**	**589**	**111**	**1,698**	**1,778**	**672**	**1**	**5,216**

New York

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**591**	7	7	72	12	0	0	**688**
Cropland	71	**4,952**	463	241	140	3	43	**5,912**
Pastureland	97	415	**2,226**	1,034	128	3	9	**3,911**
Forest land	47	29	23	**16,336**	287	15	2	**16,738**
Urban	1	5	1	12	**2,617**	0	0	**2,636**
Water	2	8	3	8	0	**1,454**	0	**1,475**
1997 total	**808**	**5,417**	**2,722**	**17,702**	**3,184**	**1,475**	**54**	**31,361**

Ohio

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**676**	119	42	170	24	1	4	**1,035**
Cropland	184	**10,881**	393	216	446	16	311	**12,447**
Pastureland	105	518	**1,496**	563	87	9	9	**2,786**
Forest land	66	92	72	**6,118**	286	23	1	**6,658**
Urban	0	7	2	6	**2,768**	0	0	**2,783**
Water	1	9	3	8	0	**715**	0	**735**
1997 total	**1,032**	**11,627**	**2,006**	**7,081**	**3,611**	**764**	**324**	**26,445**

[1] See footnote on page 75.

Appendix 1–H. Change in land cover/use[1] from 1982 to 1997 in the Northern United States by State (cont.)

Pennsylvania

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**622**	61	45	224	24	0	0	**977**
Cropland	109	**4,943**	164	211	379	4	81	**5,892**
Pastureland	57	376	**1,573**	444	149	3	9	**2,612**
Forest land	143	86	60	**14,587**	621	12	0	**15,508**
Urban	1	2	2	5	**2,810**	0	0	**2,819**
Water	0	3	1	7	0	**1,176**	0	**1,187**
1997 total	**932**	**5,471**	**1,845**	**15,478**	**3,983**	**1,196**	**90**	**28,995**

Rhode Island

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**21**	1	0	3	1	0	0	**25**
Cropland	1	**17**	4	1	5	0	0	**27**
Pastureland	1	3	**20**	9	2	0	0	**35**
Forest land	1	1	1	**374**	23	1	0	**401**
Urban	0	0	0	0	**167**	0	0	**168**
Water	0	0	0	1	3	**154**	0	**157**
1997 total	**24**	**22**	**25**	**387**	**201**	**155**	**0**	**813**

Vermont

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**66**	2	0	7	2	0	0	**76**
Cropland	5	**533**	71	14	15	11	0	**648**
Pastureland	4	64	**253**	115	8	2	0	**446**
Forest land	12	7	15	**4,012**	51	60	0	**4,157**
Urban	0	0	0	1	**241**	0	0	**243**
Water	0	0	0	2	0	**581**	0	**583**
1997 total	**88**	**607**	**338**	**4,150**	**318**	**654**	**0**	**6,154**

[1] See footnote on page 75.

Appendix 1–H. Change in land cover/use[1] from 1982 to 1997 in the Northern United States by State (cont.)

West Virginia

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**128**	3	35	82	6	0	0	**253**
Cropland	32	**752**	170	76	54	12	0	**1,095**
Pastureland	38	95	**1,174**	524	48	15	0	**1,893**
Forest land	82	13	147	**9,889**	190	91	0	**10,413**
Urban	0	1	1	6	**576**	0	0	**584**
Water	0	1	0	5	0	**1,265**	0	**1,271**
1997 total	**279**	**864**	**1,527**	**10,582**	**874**	**1,383**	**0**	**15,508**

Wisconsin

Land cover/use in 1982	Land cover/use in 1997							1982 total
	Other	Cropland	Pasture-land	Forest land	Urban	Water	CRP land	
				Thousand acres				
Other	**1,477**	51	16	73	14	1	3	**1,636**
Cropland	115	**9,921**	500	68	229	11	614	**11,457**
Pastureland	31	561	**2,436**	379	59	3	45	**3,514**
Forest land	34	67	37	**13,904**	145	30	0	**14,215**
Urban	0	4	3	11	**1,971**	0	0	**1,989**
Water	1	9	3	13	0	**3,083**	0	**3,108**
1997 total	**1,658**	**10,613**	**2,994**	**14,448**	**2,418**	**3,128**	**661**	**35,920**

[1] See footnote on page 75.

Appendix 1–H. Change in land cover/use[1] from 1982 to 1997 in the Northern United States by State (cont.)

[1]The 1982 land cover/use totals are listed in the right-hand vertical column, titled "1982 total." The 1997 land cover/use totals are listed in the bottom horizontal row, titled "1997 total." The number at the intersection of rows and columns with the same land cover/use designation represents acres that did not change from 1982 to 1997. Reading to the right or left of this number are the acres that were lost to another cover/use by 1997. Reading up or down from this number are the acres that were gained from another cover/use by 1997. Standard errors of the estimates are available from USDA NRCS.

Cropland—comprises cultivated cropland in row crops or close-grown crops and other cultivated cropland, for example, hay land that is in a rotation with row or close-grown crops.
Pastureland—land managed primarily for the production of introduced forage plants for livestock grazing.
Forest land—land that is at least 10 percent stocked by single-stemmed woody species of any size that will be at least 4 meters tall at maturity. Also included is land bearing evidence of natural regeneration of tree cover and not currently developed for nonforest use.
Urban—consists of residential, industrial, commercial, and institutional land.
Water—consists of permanent water, such as a perennial stream, lake, or pond with at least 25 percent open water.
CRP land—includes land under a Conservation Reserve Program (CRP) contract, a Federal program established under the Food Security Act of 1985 to assist private landowners to convert highly erodible cropland to vegetative cover for 10 years.
Rangeland—land on which the climax or potential cover is primarily native grasses, grasslike plants, forbs, or shrubs suitable for grazing and browsing, and introduced forages species that are managed like rangeland.

Source: USDA NRCS 2000.

Appendix 1–I. Species global conservation status rankings[1] for the Northern United States

Vertebrates	GX	GH	G1	G2	G3	G4	G5	Other	Total
Mammals	0	0	3	2	15	27	105	0	**152**
Birds	4	2	4	4	11	54	441	1	**521**
Reptiles	0	0	1	1	7	8	70	0	**87**
Amphibians	0	0	1	1	3	12	59	0	**76**
Freshwater fishes	4	3	6	10	32	45	233	0	**333**
Total	**8**	**5**	**15**	**18**	**68**	**146**	**908**	**1**	**1,169**

Invertebrates	GX	GH	G1	G2	G3	G4	G5	Other	Total
Butterflies and skippers	0	0	1	5	22	32	183	0	**243**
Crayfishes	0	0	1	13	5	16	32	0	**67**
Freshwater mussels	7	1	17	9	15	24	36	2	**111**
Dragonflies and damselflies	0	0	2	10	20	50	188	1	**271**
Tiger beetles	0	0	1	1	2	3	26	0	**33**
Total	**7**	**1**	**22**	**38**	**64**	**125**	**465**	**3**	**725**

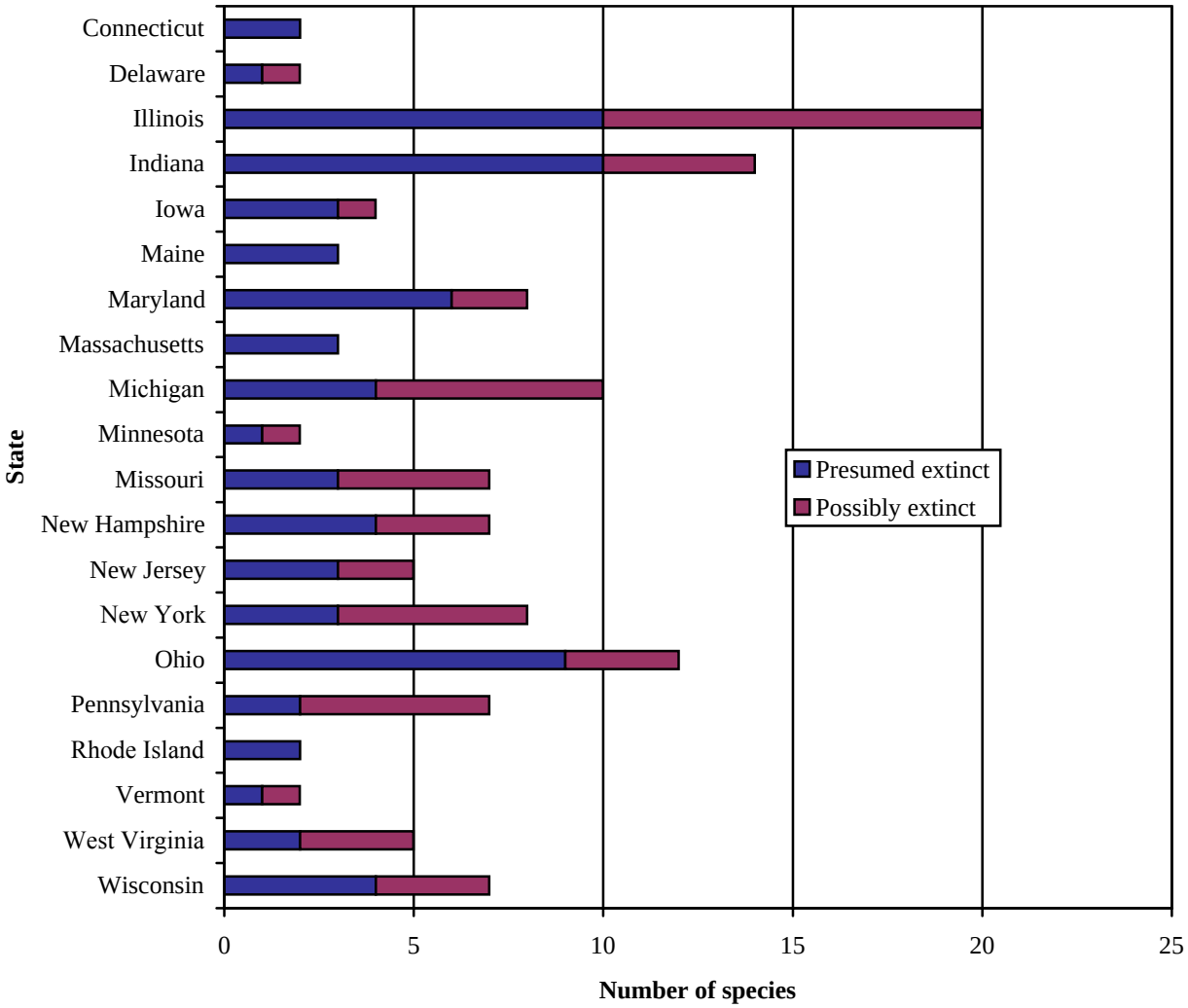
Vascular Plants	GX	GH	G1	G2	G3	G4	G5	Other	Total
Flowering	0	4	31	83	168	780	2,704	22	**3,792**
Conifers	0	0	0	0	0	2	23	0	**25**
Ferns	0	0	3	5	11	29	110	0	**158**
Total	**0**	**4**	**34**	**88**	**179**	**811**	**2,837**	**22**	**3,975**

Totals	No.	G Ranks
Presumed/possibly extinct	25	GX–GH
Critically imperiled	71	G1
Imperiled	144	G2
Vulnerable	311	G3
Other	26	Other
Secure/apparently secure	5,292	G4–G5
Total	**5,869**	

[1]**GX** **Presumed Extinct**—Not located despite intensive searches
GH **Possibly Extinct**—Of historical occurrence; still some hope of rediscovery
G1 **Critically Imperiled**—Typically 5 or fewer occurrences or 1,000 or fewer individuals
G2 **Imperiled**—Typically 6–20 occurrences or 1,000-3,000 individuals
G3 **Vulnerable**—Typically 20–100 occurrences or 3,000-10,000 individuals
G4 **Apparently Secure**—Uncommon but not rare; some cause for long-term concern; usually more than 100 occurrences and 10,000 individuals
G5 **Secure**—Common; widespread and abundant

Source: TNC and ABI 2000.

Appendix 1–J. Number of species extinctions in the Northern United States by State



Source: TNC 1997.

Appendix 1–K. 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[2]
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[2]
Roseate tern	*Sterna dougallii dougallii*	E
Reptiles		
Bog turtle	*Clemmys muhlenbergii*	T
Copperbelly water snake	*Nerodia erythrogaster neglecta*	T
Green sea turtle[3]	*Chelonia mydas*	T
Hawksbill sea turtle[3]	*Eretmochelys imbricata*	E
Kemp's (=Atlantic) ridley sea turtle[3]	*Lepidochelys kempii*	E
Lake Erie water snake	*Nerodia sipedon insularum*	T
Leatherback sea turtle[3]	*Dermochelys coriacea*	E
Loggerhead sea turtle[3]	*Caretta caretta*	T
Northern (=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 surgeon	*Acipenser brevirostrum*	E
Topeka shiner	*Notropis topeka*	E
Crustaceans		
Hay's Spring amphipod	*Stygobromus hayi*	E
Illinois cave amphipod	*Gammarus acherondytes*	E
Clams		
Clubshell	*Pleurobema clava*	E
Cracking pearlymussel	*Hemistena lata*	E
Curtis' pearlymussel	*Epioblasma florentina curtisi*	E
Dwarf wedgemussel	*Alasmidonta heterodon*	E
Fanshell	*Cyprogenia stegaria*	E

[1]E = endangered
T = threatened
[2]Endangered in one part of its range and threatened in another.
[3]Denotes coastal species. (The six oceanic species are not included in this list.)
Source: McLellan 1998, USDI Fish and Wildlife Service 1999a.

Appendix 1–K. Federal threatened and endangered species in the Northern United States (cont.)

Common name	Scientific name	Status[1]
Fat pocketbook	*Potamilus capax*	E
Higgins eye pearlymussel	*Lampsilis higginsi*	E
James spinymussel	*Pleurobema collina*	E
Northern riffleshell	*Epioblasma torulosa rangiana*	E
Orangefoot pimpleback 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 torulosa torulosa*	E
White cat's paw pearlymussel	*Epioblasma obliquata perobliqua*	E
White wartyback pearlymussel	*Plethobasus cicatricosus*	E
Winged mapleleaf mussel	*Quadrula 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 scolopendium* 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 robbinsi* var. *jesupii*	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

[1]E = endangered
T = threatened
Source: McLellan 1998, USDI Fish and Wildlife Service 1999a.

Appendix 1–K. Federal threatened and endangered species in the Northern United States (cont.)

Common name	Scientific name	Status[1]
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
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

[1]E = endangered
T = threatened
Source: McLellan 1998, USDI Fish and Wildlife Service 1999a.

Criterion 2

Maintenance of Productive Capacity of Forest Ecosystems

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Criterion 2. Maintenance of Productive Capacity of Forest Ecosystems

Thomas Schmidt,[1] Thomas Birch,[2] Constance Carpenter,[3] Daniel Wendt,[1] and Mary Carol Koester[4]

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 nontimber 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, benefits such as soil erosion protection, water quality enhancement, spiritual retreat, or areas for active motorized and nonmotorized recreation.

Indicator 10. Area of forest land and net area of forest land available for timber production

Roughly 41 percent (169 million acres) of the 413 million acres of land in the Northern United States is forested. These forest lands include all land that is at least 10 percent stocked by forest trees of any size and land that formerly had trees and will be naturally or artificially regenerated (Hansen and others 1992).

The USDA Forest Service Forest Inventory and Analysis Program categorizes forest land into three land management classes: timberland, other forest land, and reserved land. Roughly 159 million acres (93 percent) of forest land in the Northern United States is classified as timberland (figure 2.1). Of the remaining forest land, 2.8 million acres (2 percent) is other forest land and 8.2 million acres (5 percent) is reserved forest land. Land class information by State is in appendix 2–A.

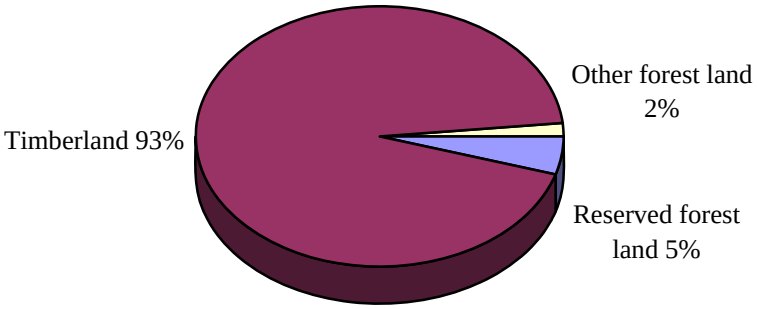

Figure 2.1 **Forest land use in the Northern United States**. Ninety-three percent of the forest land is suitable for timber production (USDA Forest Service 1999b[1]).

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

Timberland is forest land that meets minimum productivity standards and is

[1]USDA Forest Service, North Central Research Station, St. Paul, MN
[2]USDA Forest Service, Northeastern Research Station, Newtown Square, PA
[3]USDA Forest Service, Northeastern Area State and Private Forestry, Durham, NH
[4]USDA Forest Service, Northeastern Area State and Private Forestry, Newtown Square, PA

potentially available for harvest. Conditions not considered in the classification of timberland may also reduce the amount of forest land available for harvest. These include physical constraints that affect equipment operability such as steep slope or wetness, economic constraints such as poor sale value or costly access-road construction, and social constraints such as landowner objectives that preclude timber production.

The amount of timberland increased between 1977 and 1997, but has begun to decrease (figure 2.2). Past increases in forest land were made at the expense of agricultural lands. Recent and projected losses of forest land may be due to development trends (USDA NRCS 2000).

Land in the **other forest land** class does not meet timberland productivity standards, but certainly some of the trees are harvestable. Sustained yields of timber can occur when consideration is made of specific site conditions. For example, longer rotation periods may appropriately protect environmental values while providing economic benefits. Regardless, these lands provide nontimber benefits such as recreation, wildlife, water quality, and forage production.

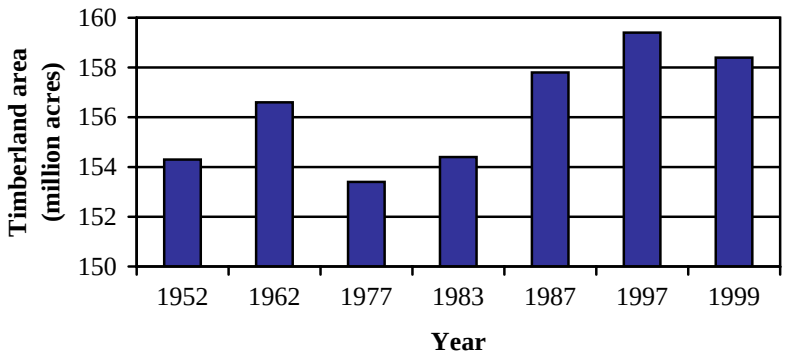

Figure 2.2. **Trends in timberland area in the Northern United States, 1952–1999**. Timberland area increased from 1977 to 1997, but has begun to decrease (Smith and others 2001, USDA Forest Service 1999b[1]).

[1]Inventory follows methods in Hansen and others (1992).
Note: Data was collected for individual States on varying cycles (see appendix 2–A); regional data was summarized periodically as shown.

The 8.2 million acres of reserved forest land is publicly owned land withdrawn from timber use by statute or administrative regulation. An estimated 7.9 million acres of the reserved land is timberland.

Land Ownership

In the Northern United States in 1992, timber harvest decisions on roughly 130 million acres of forest land were made by an estimated 3.9 million private forest landowners. Although the majority of landowners do not intend to harvest in the next 10 years, the majority of the private forest lands in the region have some potential to be harvested. Only 1 percent of private landowners hold land primarily for timber production; however, these people control 19 percent of the land (figure 2.3). Likewise, about half of private landowners have harvesting experience and control 75 percent of private forest land (figure 2.4). Although only 35 percent of private forest landowners state they intend to harvest in the next 10 years, they own 61 percent of the private acreage (figure 2.5) (Birch 1996b).

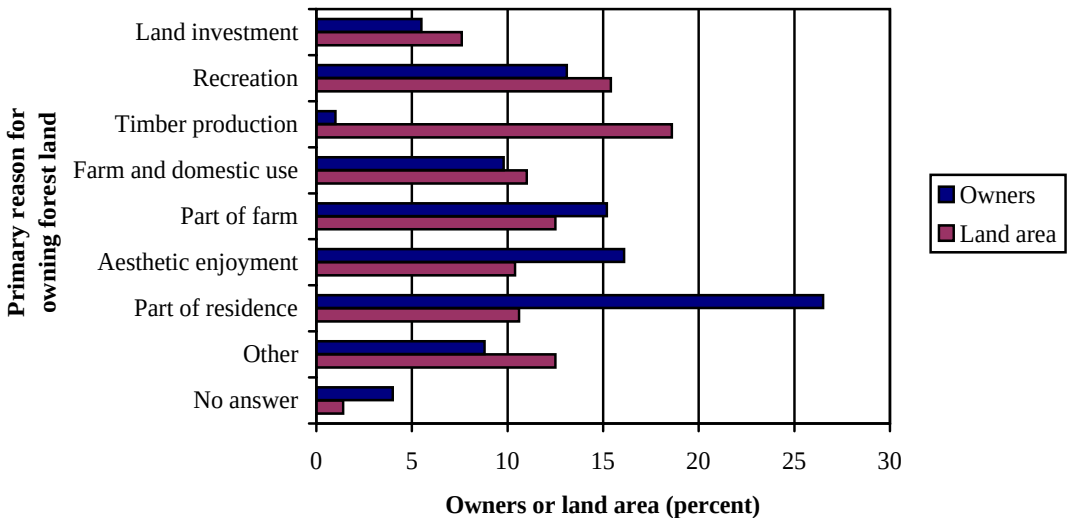

Figure 2.3. **Distribution of private ownerships, by primary reason for owning forest land, Northern United States, 1994**. Only 1 percent of the landowners hold land primarily for timber production, but they own 19 percent of the forest land (Birch 1996a).

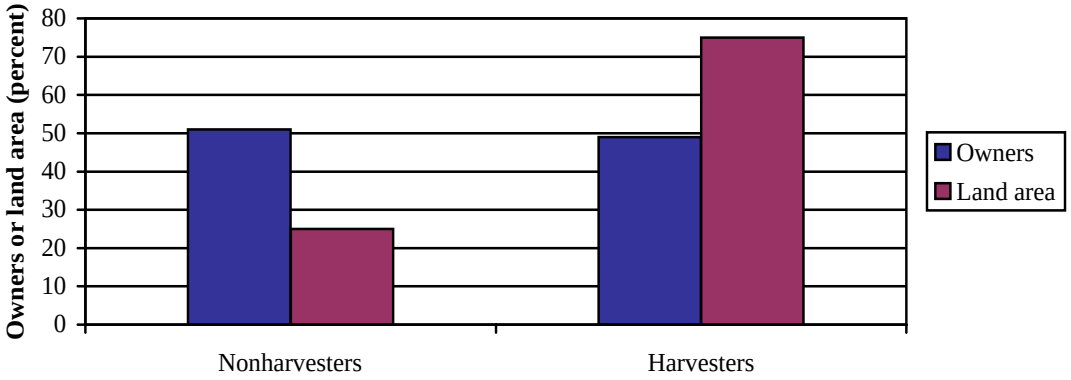

Figure 2.4. **Harvest activity by private owners in the Northern United States**. Roughly half of private forest landowners have harvested timber. These owners control three-quarters of the private forest land area (Birch 1996a).

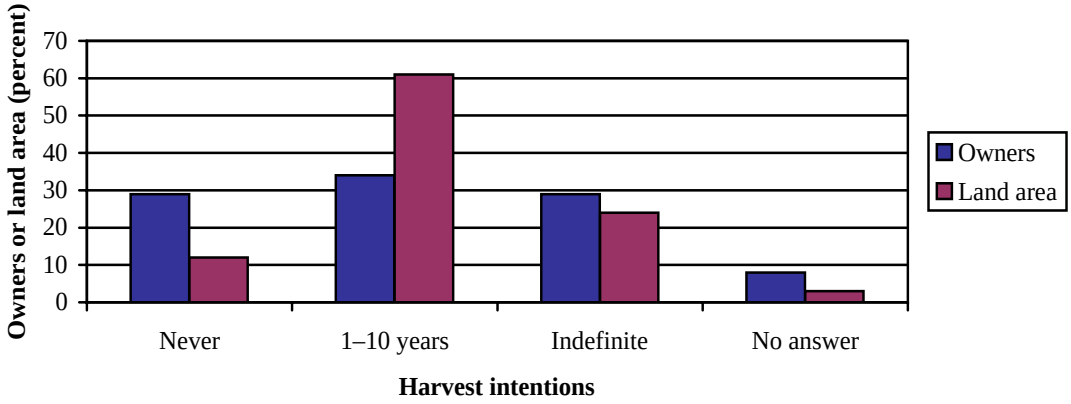

Figure 2.5. **Harvest intentions of private owners in the Northern United States, 1994**. The majority of private forest land in the region will be considered for harvest in the next 10 years (Birch 1996a).

Timberland availability for harvest can be affected by the parcel size and land tenure. Landowners with long tenure or large land parcels are more likely to harvest timber from their land. The distribution of ownership by tract size class changed between 1978 and 1994 (figure 2.6). More than 25 percent of private forest land is held in ownerships of fewer than 100 acres each. The amount of land held in tracts of over 100 acres decreased between 1978 and 1994. Corporate and partnership ownership decreased during the same period (Birch 1996a).

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 in 1994, 75 percent of all private landowners owned less than 20 acres of timberland (Birch 1996b). As a comparison, in the Central States 67 percent and in the Lake States 53 percent of all private landowners had tracts of less than 20 acres.

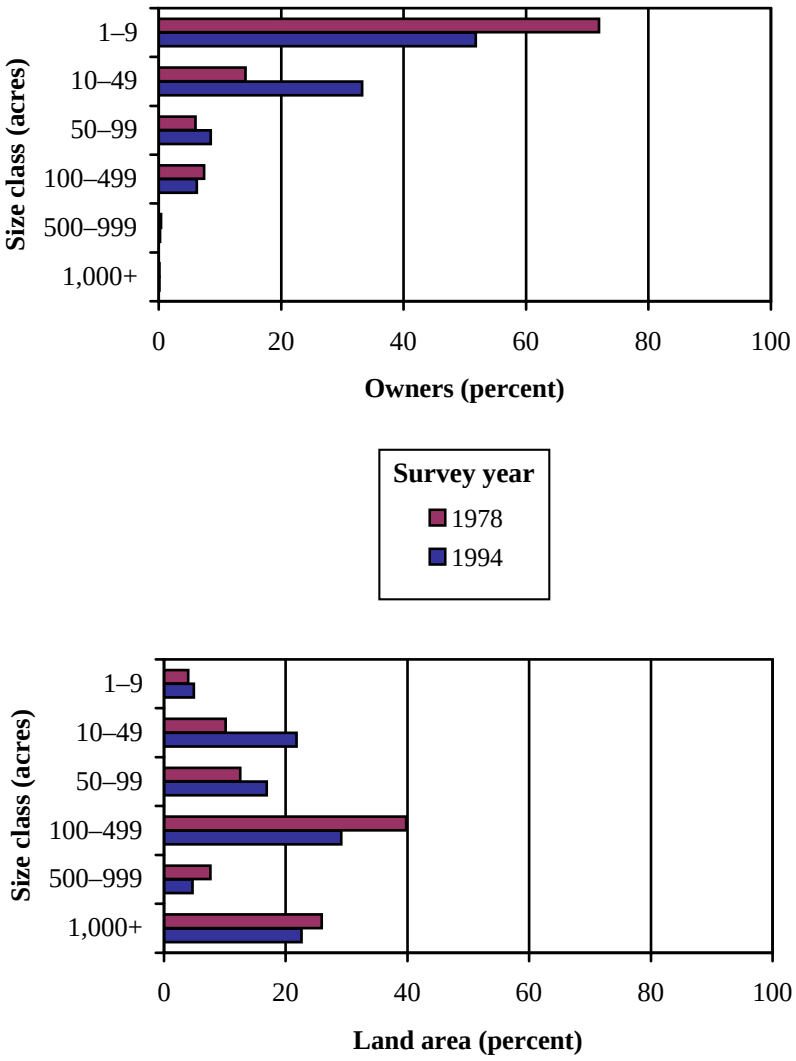

Figure 2.6. **Distribution of private ownerships, by size class, in the Northern United States**. Landowner surveys were conducted in 1978 and 1994. The ownership by size class is shown as a percentage of the total number of owners (above) and the total land area owned (below). The majority of private landowners own less than 10 acres of land, but the majority of private forest land acreage remains in tracts greater than 100 acres in size (Birch 1996a).

Operability

Operability is defined as the ease or difficulty of managing or harvesting timber because of physical conditions. In Michigan in 1980, 40 percent of the timberland was classified as being in operability class III (poorest category of potential operability) (Hansen and Hahn 1987). Some of this land will be harvested, but much of it will be left for its other values.

Indicator 11. Total growing stock of both merchantable and nonmerchantable tree species on forest land available for timber production

Growing stock is a classification that includes only live trees meeting standards for quality or vigor. **Cull trees**, live trees with poor form, rot, and defects, are not considered in growing-stock calculations. **Growing-stock volume** is calculated for growing stock that is at least 5.0 inches in diameter when measured at breast height (4.5 feet above ground level). Growing-stock inventory figures change constantly owing to forest growth, mortality, timber harvest, removals related to forest resource management, and losses resulting from conversion of forest to other land uses.

Growing-stock volume on timberland in the Northern United States more than doubled between 1953 and 1999, from roughly 104 billion ft^3 to 215 billion ft^3 (figure 2.7) (Smith and others 2001, USDA Forest Service 1999b). Net annual growth increased by 45 percent and removals by 54 percent during that 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. New 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.

Hardwoods account for 77 percent of total growing-stock volume and are the predominant source of volume in all provinces (figure 2.8). The Laurentian Mixed Forest Province 212 has roughly 35 percent of the growing-stock volume and the largest shares of hardwood and softwood volumes.

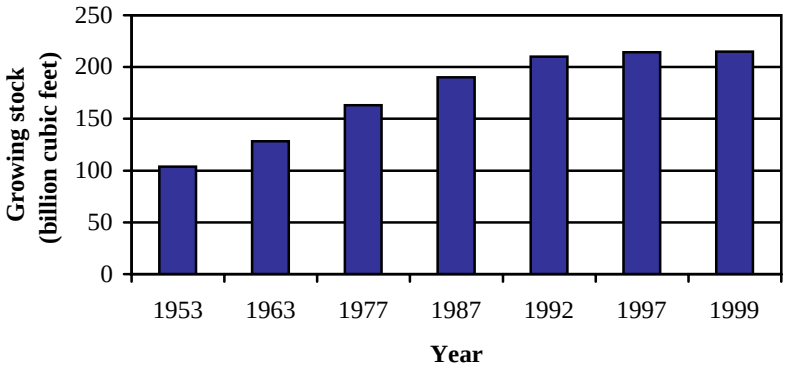

Figure 2.7. **Growing-stock volume on timberlands in the Northern United States**. Volume increased between 1953 and 1999 (Smith and others 2001, USDA Forest Service 1999b[1]).

[1]Inventory follows methods in Hansen and others (1992).
Note: Data was collected on alternating cycles of 5 or 10 years and summarized periodically as shown.

Growth Potential

Site productivity is an important consideration in determining the productive capacity of forest ecosystems. Timberland is defined by the inherent capability to produce at least 20 ft^3 of wood fiber per acre per year. The total potential production would be dramatically different if all the timberland were on poor sites than if all of timberland were on excellent sites. In the Northern United States in 1992, 19 percent of inventoried timberland was on **excellent sites** (potential productivity of more than 85 ft^3/acre/year), and 34 percent was on **good sites** (potential productivity between 50 and 84 ft^3/acre/year). The remaining 47 percent of timberland was on sites with **average to low productivity** (less than 50 ft^3/acre/year).

Based on potential productivity and site index measures, the Northern United States has highly productive timberland capable of producing a wide variety of forest products at a rate above the national average. Nonetheless, many timberlands in the Northern United States currently produce less wood fiber than they could because stands are understocked or past optimal rotation age. For example, across the United States, average annual net growth on timberland is estimated to be 38 ft^3/acre/year whereas the potential productivity is estimated at 74 ft^3/acre/year (Spurr and Vaux 1976).

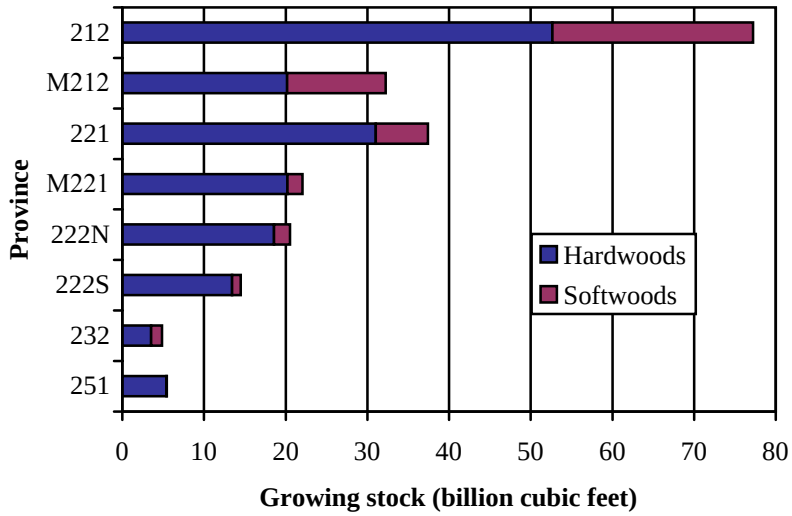

Figure 2.8. **Distribution of hardwood and softwood growing stock on timberland in the Northern United States by province** (USDA Forest Service 1999b[1]). Provinces 231 and 234 have been omitted because the amounts are too small to be evident on the graph.

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

There are many opportunities to improve the productivity on the Northern United States' timberlands. For example, enhancing stocking levels on understocked sites will enable them to produce greater volumes of wood. **Stocking** is the degree of occupancy of land by trees compared with amounts required to fully use the growth potential of the land. Stocking is measured by basal area or number of trees by size and spacing, or both. In the Northern United States, roughly 440,000 acres, less than 0.3 percent of all timberland, is nonstocked (USDA Forest Service 1999). A strategy of enhancing stocking on the most productive sites may lessen the harvesting pressure on sites that are physically or biologically sensitive.

Indicator 12. The area and growing stock of plantations of native and exotic species

Plantations have been a part of forest management since the early 1900s. However, most forests in the Northern United States are managed to encourage natural regeneration; as a result, plantations have been less important than in other regions.

Timberland plantations were established through the Civilian Conservation Corps in the 1930s, through the Soil Bank Program in the 1950s, and by private and individual landowners with the forethought and insight to plant trees on marginally productive croplands and pasture lands. The area of timberland planted annually grew during the 1950s, declined in the 1960s, and increased steadily in the 1970s (USDA Forest Service 1982). As of 1992, there were about 3.5 million acres of timberland plantations in the Northern United States, 84 percent of which were located in the North Central region (Hansen and others 1992). This number had increased to 4.3 million acres by 1997 (Smith and others 2001).

The majority of the plantations are conifer, red pine (*Pinus resinosa*) being the most heavily planted species. Other conifer species in timberland plantations include white pine (*Pinus strobus*), jack pine (*Pinus banksiana*), and spruce (*Picea* spp.). Hardwood plantations in the Northern United States tend to be smaller in area and often contain black walnut (*Juglans nigra*) and a variety of oak species (*Quercus* spp.). These tree plantings are currently providing the benefits that were envisioned by the thousands of people who planted them. As plantations mature and are harvested, some are replanted for another rotation of trees, some revert back to natural stands, and some are converted to other land uses. The degree of change differs by State and by the type of planting established.

Annual statistics on the area of forest tree planting in the Northern United States have been published since 1930 (USDA Forest Service 1994). Results do not provide cumulative estimates of the total area of land planted in trees because it is difficult to account for plantings that are primarily designed for nontimber uses such as wildlife habitat and windbreaks. Although these plantings are not considered timber plantations, they do contribute a wide variety of benefits including wood fiber. As a result, statistics for some States show no plantations, but this does not mean that no tree plantings exist in those States.

Indicator 13. Annual removal of wood products compared to the volume determined to be sustainable

The volume of wood and nonwood forest products removed annually relative to the volume of removals that is sustainable indicates a forest's ability to provide a continuing supply of forest products. As a supplement to this traditional approach, it is useful to compare net growth and removals with inventory volume. Since net growth also depends on mortality, it is necessary to compare mortality with inventory volume. Useful indices for analyzing these relationships can be derived by expressing the three components of inventory change (growth, removals, and mortality) as proportions of inventory volume and by tracking these indices over time.

The question of what harvest volume (removals) is sustainable has been debated since the concept of sustained yield forestry was first introduced. The traditional approach has been to compare removals with net growth, expressed as volume on an annual basis. If net growth exceeds removals, then inventory volume increases. If removals exceed net growth, then inventory volume decreases; if removals and net growth are in balance, then inventory volume remains level. Analyses involving these components focus on timberland.

Growing-stock inventory (volume) on timberland in the Northern United States more than doubled from 1952 to 1999, rising from about 104 billion ft^3 to 215 billion ft^3 (table 2.1). Net annual growth increased by 45 percent and removals by 54 percent during that time period, yielding a growth-to-removals ratio of about 1.8:1. By 2040, the total growing stock is projected to be 23 percent higher than in 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.

Hardwoods accounted for 77 percent of growing-stock inventory in 1999 and were more than three times softwood inventories. The hardwood growing-stock inventory more than doubled between 1952 and 1999, and the volume in net annual growth has increased steadily. The growth-to-removals ratio for the last half of the 20th century has held steady for hardwoods

Table 2.1. **Changes in inventory, growth, and removals on timberland in the Northern United States** (Haynes 1990, Smith and others 2001, USDA Forest Service 1999b[1]).

	1952	1977	1987	1997	1999	2040 (projected)
			Million cubic feet			
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.

at 2:1. As 2040 approaches, the hardwood growing-stock inventory will continue to increase while the hardwood growth-to-removals ratio will decrease to 1.2:1.

From 1952 to 1999, the softwood growing-stock inventory on timberland in the Northern United States increased by about 22 billion ft^3. Both net annual growth and removals were higher in 1999 than at mid-century. The growth-to-removals ratio decreased only slightly, from 1.6:1 to 1.5:1, although it was as high as 2.3:1 in the late 1970s. By 2040, it is projected to approach 1.1:1.

This projected downward trend in growth-to-removals ratios represents a substantial 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 again reaching maturity. With this advance in age, growth rates have slowed and harvesting has increased.

Inventory information was summarized by province to examine regional differences in inventory and growth-to-removals ratios. Hardwoods are the majority inventory class in all Northern U.S. provinces (see figure 2.8). The Laurentian Mixed Forest Province 212 has most of the total growing-stock inventory, the largest shares of both hardwood and softwood inventories, and growth-to-removals ratios most reflective of the regional and forest class averages (table 2.2). Softwoods are about a third of the growing stock in the New England-Adirondack Mountains M212 and Province 212 but less of a component of other provinces (appendix 2–B).

Net growth exceeds removals for hardwoods and softwoods in all ecosystems of the Northern United States except the M212, where softwood removals are greater than annual growth. Regional differences in growth and removals are most evident for softwoods, although some variation exists for hardwoods as well. Future analyses might look at the reasons for these differences.

Table 2.2. **Growth-to-removals ratios of hardwoods and softwoods by province in the Northern United States** (USDA Forest Service 1999b[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).
Note: ns = data not sufficient for calculation

Indicator 14. Annual removal of nontimber forest products (e.g., furbearers, berries, mushrooms, game) compared to the level determined to be sustainable

Nontimber forest products include game animals; furbearing mammals; maple syrup; nuts and seeds such as persimmons, walnuts, pecans, and hickory nuts; berries; mushrooms; oils; foliage; peat; fuelwood; and forage. Items such as pine cones, buckeyes (*Aesculus glabra*), bittersweet (*Celastrus scandens*), grapevines, club moss (*Lycopodium clavatum*), and sheet moss (*Hypnum* spp.) are collected for crafts. Medicinal plants collected include ginseng (*Panax quinquefolium*), goldenseal (*Hydrastus canadensis*), coneflower (*Echinacea purpurea*), black cohosh (*Aetaea racemosa*), blue cohosh (*Caulophyllum thalictroides*), mayapple (*Podophyllum peltatum*), and blood-root (*Sanguinaria canadensis*). Nonmarket products such as watershed protection (criterion 4), biological diversity conservation (criterion 1), recreation and spiritual values (criterion 6), and carbon sequestration (criterion 5) are discussed in other chapters.

Recognition of the economic importance and potential impacts of nontimber harvest activities is just emerging. The majority of nontimber products are not regulated so there is no systematic effort to collect data. Although there are a wide variety of studies related to nontimber products conducted on a local scale, they are not readily synthesized for regional comparisons or trend analysis. Some trends can be gleaned, however, where permits are issued and local studies have been conducted. For example, a recent study on the Hiawatha National Forest in Michigan indicated that of 138 special forest products collected in and around the forest, 60 percent were consumed directly or given as gifts, and only 40 percent were sold (Emery 1997). Between 1992 and 1997 on the Hoosier National Forest in Indiana, permittees most often collected 15 to 90 pounds of goldenseal and 1 to 3 pounds of ginseng. Another 50 species were also collected, although less frequently. In 1992, one collector filled an order for 40,000 pounds of sumac (*Rhus* spp.) bark; in 1993 the greatest demand was for sassafras (*Sassafras albidum*) leaves (Olsen 1997).

Hundreds of tons of club moss are gathered from national forests each year. Recently, ginseng has become scarce on national forests in the Northern United States and now is listed as threatened in many States (Padley 1997). Ginseng has been regulated since 1975 and is now cultivated in Wisconsin to meet demand. It takes about 100 ginseng roots to make a pound.

Plant theft from national forests is another problem. For example, since the 1960s showy orchids (*Galearis spectabilis*) have nearly vanished from national forests in the Central States because of overharvesting.

Activities such as hunting, fur-trapping, and commercial seed or berry collecting are usually regulated under a permit system. Traditionally, harvest regulations for furbearers and game are set with the intention of sustainability. Species managed under State jurisdiction in the Northern United States include big game, small game, furbearers, and recreational fish. Each State can vary in how regulations are promulgated. Species under Federal jurisdiction include migratory birds and commercial fisheries. In theory, sustainability for furbearers and game is achieved such that annual mortality is balanced by reproduction. In reality, populations are in flux because of unanticipated events such as weather or disease. Thus, the setting of seasons and bag limits is both an art and a science.

Gathering of berries, mushrooms, and other specialty products is increasing in popularity. The role of these products in ecosystem functions and processes is not well understood. Studies in other regions, such as the Pacific Northwest (Piltz and Molina 1996), show a tremendous economic and cultural contribution from specialty products, but to date studies have not been completed for the Northern United States. Harvest data for game and furbearers are maintained by public agencies in each State, as are data on populations; however, the quality of the data differs by State.

Nontimber products such as berries depend on habitat for their production. The collection of berries does not impact their sustainability since only the fruits, not the plants, are harvested. This also holds true for other nontimber products, such as mushrooms, nuts, and seeds. The production of many nontimber forest products depends on keeping the forest base in place and using the benefits while not impacting the overall health of the ecosystem.

In cases where harvest of the nontimber product involves removing plants, such as with oils, fuelwood, foliage, and medicinal plants, if the habitat is maintained, then management can encourage replacement of plants, and sustainability is likely.

Summary and Conclusions

Roughly 169 million acres of the 413 million acres of land in the Northern United States is forested. Forest land and timberland acreage has been increasing for over two decades, but this trend cannot last if development pressure continues apace. Roughly 94 percent of the forest land is suited for timber production. The potential to increase production by expanding the timberland base is limited. In addition, social and cultural constraints such as parcelization of forest land and changing landowner values reduce acreage available for harvest.

Extensive areas of timberland in the Northern United States are understocked or past optimal rotation age. Natural regeneration is the predominant regeneration method. Oak regeneration is a concern across the entire Northern United States. Plantations are a minor component of Northern U.S. timberland.

Silvicultural techniques to increase tree stocking and growth per acre are important for the future. Increased focus on intensive forest management could increase production of wood fiber and lessen the pressure on ecologically sensitive lands. Forest management activities, such as thinning and planting genetically superior trees, are important for the future. Investments in technology to generate engineered wood fiber products can help decrease the need for larger trees and lessen harvesting pressures.

Demand for nonwood forest products is increasing. Inventories of supply, growth, and removals of living products are not readily available. Intensive management for high-demand species such as ginseng may be one key to their sustainability. Maintenance of habitat and plant vigor for seed and fruit harvest is likely to ensure sustainability of these types of nonwood products.

Appendix 2–A. Estimated total land area by land class, Northern United States

State	Inv. year	All land	Total forested	Timberland	Other forest land	Reserved forest land	Nonforest land
				Thousand acres			
Connecticut	1985	3,101.0	1,862.8	1,814.6	17.2	31.1	1,238.4
Delaware	1986	1,236.7	389.5	376.4	10.2	2.9	847.2
Illinois	1985	35,630.0	4,265.5	4,029.9	—	235.6	31,364.5
Indiana	1986	23,002.1	4,439.2	4,295.8	—	143.4	18,562.9
Iowa	1990	35,817.0	2,050.2	1,943.5	18.9	87.8	33,766.8
Maine	1995	19,753.5	17,699.4	16,952.2	380.2	367.0	2,054.0
Maryland	1986	6,291.6	2,699.5	2,423.5	123.1	153.0	3,592.0
Massachusetts	1985	5,016.5	3,264.1	2,965.6	137.2	161.4	1,752.0
Michigan	1993	36,358.2	19,280.8	18,615.9	90.2	574.7	17,077.4
Minnesota	1990	50,910.9	16,681.1	14,723.2	871.1	1,086.8	34,229.8
Missouri	1989	44,124.9	13,998.2	13,370.8	311.2	316.2	30,126.7
New Hampshire	1983	5,637.1	4,868.6	4,812.0	56.6	—	768.4
New Jersey	1987	4,698.6	1,889.1	1,856.7	—	32.4	2,809.2
New York[1]	1993	30,090.1	18,889.1	15,405.6	134.7	3,348.5	11,200.4
Ohio	1991	26,278.2	7,917.4	7,567.3	2.5	346.5	18,361.3
Pennsylvania	1989	28,645.4	16,910.5	15,873.0	85.4	952.0	11,735.5
Rhode Island	1985	668.8	409.2	356.2	37.0	16.0	259.6
Vermont	1983	5,818.8	4,436.1	4,422.1	14.0	—	1,382.6
West Virginia	1989	15,330.1	12,028.8	11,917.6	27.0	84.3	3,301.7
Wisconsin	1996	34,759.5	15,963.0	15,700.9	65.2	197.0	18,796.5
Total		**413,169.0**	**169,942.1**	**159,422.8**	**2,381.7**	**8,136.6**	**243,226.9**

[1]Includes 2,902,900 acres in Adirondack and Catskill Preserves.
Source: USDA Forest Service 1999b. Inventory follows methods in Hansen and others (1992).

Appendix 2–B. Volume, net growth, annual mortality, and annual removals of growing stock on timberland in millions of cubic feet, by province for the Northern United States

Province	Current volume			New growth		
	Softwood	Hardwood	Total	Softwood	Hardwood	Total
	Million cubic feet					
212	24,610	52,646	77,256	644.1	1,375.3	2,019.4
M212	12,103	20,191	32,294	190.8	401.2	592.0
221	6,408	31,040	37,447	143.0	815.7	958.7
M221	1,870	20,217	22,087	44.9	472.5	517.4
222N	2,024	18,559	20,583	78.8	528.8	607.6
222S	1,119	13,418	14,537	37.2	380.0	417.3
231	1	104	105	0.0	7.6	7.6
232	1,354	3,544	4,898	38.3	80.4	118.7
234	12	162	174	0.1	5.0	5.1
251	68	5,322	5,391	2.2	136.5	138.7
Total	**49,568**	**165,203**	**214,771**	**1,179.4**	**4,203.1**	**5,382.5**

Province	Annual mortality			Annual removals		
	Softwood	Hardwood	Total	Softwood	Hardwood	Total
	Million cubic feet					
212	240.1	437.6	677.7	351.8	689.1	1,040.9
M212	142.4	120.9	263.3	261.9	202.6	464.5
221	26.6	160.2	186.8	78.3	368.9	447.2
M221	16.2	130.1	146.3	16.6	193.4	210.1
222N	11.8	143.1	154.9	35.1	404.9	440.0
222S	5.9	111.1	117.1	7.7	161.5	169.2
231	0.0	0.7	0.7	0.0	1.0	1.0
232	13.5	30.0	43.5	30.5	68.3	98.8
234	0.1	2.2	2.3	0.0	2.2	2.2
251	0.6	58.5	59.1	0.5	54.5	55.0
Total	**457.2**	**1,194.4**	**1,651.5**	**782.3**	**2,146.4**	**2,928.7**

Source: USDA Forest Service 1999b. Inventory follows methods in Hansen and others (1992).

Criterion 3

Maintenance of Forest Ecosystem Health and Vitality

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Criterion 3. Maintenance of Forest Ecosystem Health and Vitality

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Forests are valued not only for the various products they provide, but also for recreation, wildlife, fisheries, water quality, and aesthetics. To ensure the future benefits of the Nation's urban and rural forests, it is necessary to keep forests, forested watersheds, and forest ecosystems in a healthy state. Forest health is a term that describes forest condition in relation to values, needs, and ecosystem functions.

The general health of the forest is difficult to assess at any one point in time, as it is dynamic. **Forest health** can be defined as the ability of trees and forests to recover from stressors, both natural and human induced. Measures of forest health include the age and composition of the forest, trends in tree growth and mortality, tree crown condition, vulnerability to forest health stressors and frequency of occurrence, and the condition of soil, water, and wildlife.

Concerns have been raised about the overall health of the Nation's forests and the threats from various biotic and abiotic factors including insect, pathogen, and plant pests; herbivores; severe weather; global climate change; and air pollution. Native forest pests such as spruce budworm (*Choristoneura fumiferana*) cause varying degrees of damage from year to year and decade to decade. However, nonnative, or **exotic, insects and pathogens** pose the major threat. These introduced pests usually have no natural factors in their new environment that can control their population. Recent damage from severe weather has included drought, floods, tornadoes, and ice storms. The effects of global climate change are currently being debated. Air pollution impacts on northern forests have been documented, including the damaging effects of ozone and acid deposition.

Combinations of stressors, such as exotic insects and pathogens along with drought, cause the greatest impact. Various stressors can result in a decline in forest stands from tree dieback and deterioration. This decline may eventually affect urban tree composition, and forest composition and productivity. It is important to maintain healthy forests that are resilient to stressors. Annually monitoring the forests of the Northern United States through the Forest Health Monitoring Program and other State/Federal cooperative forest health surveys provides valuable information on the status and trends in changes in forest health caused by the various stress factors. The information is used to assess forest ecosystem health over time.

Disturbance plays an important role in the forest ecosystem. A key question is whether the magnitude of disturbance is outside the range of historical variation. The impact from native pests varies annually, but overall the forest is resilient to these endemic factors. However, new factors—including forest management practices, air pollution, and exotic invasive organisms—have begun affecting urban and rural forests. These new factors, especially when they occur in combination, have a greater potential to affect forest health.

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Indicator 15. 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)

Native Insects and Pathogens

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 3.1). Native insects in the Northern United States defoliated over 40 million acres between 1993 and 2001. Acres defoliated annually ranged between 1 and 6 million until 2001 when about 15 million acres were defoliated owing, primarily, to a forest tent caterpillar (*Malacosoma disstria*) outbreak in the Lake States.

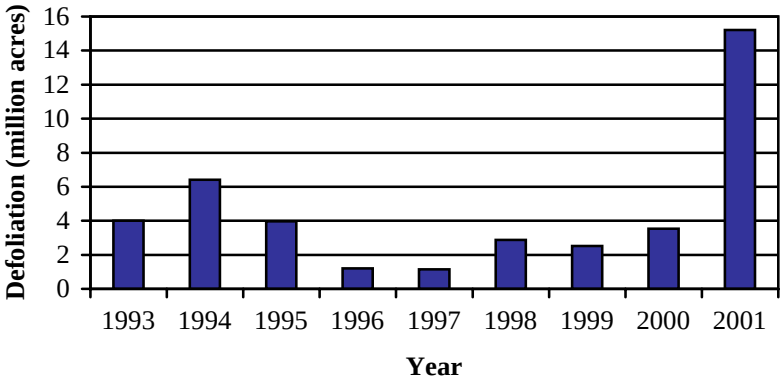

Figure 3.1. **Acres of defoliation**. Between 1993 and 2001, over 40 million acres were defoliated by native insects in the Northern United States. The large increase in 2001 was due primarily to a forest tent caterpillar outbreak in the Lake States (USDA Forest Service 1994–2002).

Historically, conifers in the Northern United States have been affected by spruce budworm, jack pine budworm (*Choristoneura pinus*), and pine false webworm (*Acantholyda erythrocephala*). The hemlock looper (*Lambdina fiscellaria fiscellaria*) has caused significant dieback and mortality to eastern hemlock (*Tsuga canadensis*). The main native defoliators of oaks (*Quercus* spp.) are oak leaftier (*Croesia semipurpurana*) and oak skeletonizer (*Bucculatrix ainsliella*). Maples (*Acer* spp.) are affected by the maple leaf cutter (*Paraclemensia acerifoliella*) and other defoliators. The forest tent caterpillar has also caused extensive defoliation of hardwoods.

In 1997, native insects defoliated over 1.13 million acres of forested land in the Northern United States. Spruce budworm, jack pine budworm, pine false webworm, and red pine shoot moth (*Dioryctria resinosella*) accounted for nearly half of the total acres affected (figure 3.2). Scarlet oak sawfly (*Caliroa quercuscoccineae*), oak leaftier, and oak skeletonizer defoliated approximately 355,000 acres of black oak (*Quercus velutina*), northern red oak (*Quercus rubra*), pin oak (*Quercus palustris*), and shingle oak (*Quercus imbricaria*). This defoliation was confined mostly to Ohio, Pennsylvania, Missouri, and West Virginia, and the areas were impacted again the following year. The maple leaf cutter and the greenstriped mapleworm (*Dryocampa rubicunda*) defoliated more than 133,000 acres of red maple (*Acer rubra*) and sugar maple (*Acer saccharum*) in New York and Vermont. Wisconsin reported approximately 20,000 acres of damage to eastern hemlock by the hemlock looper.

In 1998, almost 500,000 acres were defoliated by the eastern pine looper (*Lambdina pellucidaria*) in the New Jersey Pinelands, making fire a serious concern. The jack pine budworm was active again in Michigan and Wisconsin. The forest tent caterpillar also caused severe defoliation on some areas of aspen (*Populus* spp.) and other hardwoods. In eastern Massachusetts, the fall cankerworm (*Alsophila pometaria*) defoliated 125,000 acres of maple. The most significant damage from a native pest in 1999 was caused by the forest tent caterpillar. Defoliation of aspen, basswood (*Tilia americana*), and other hardwoods occurred on over 500,000 acres in Minnesota, 163,000 acres in Michigan, and 50,000 acres in Wisconsin. Another significant native pest was the large aspen tortrix (*Choristoneura conflictana*), which defoliated over 700,000 acres of aspen forest in Michigan and Minnesota.

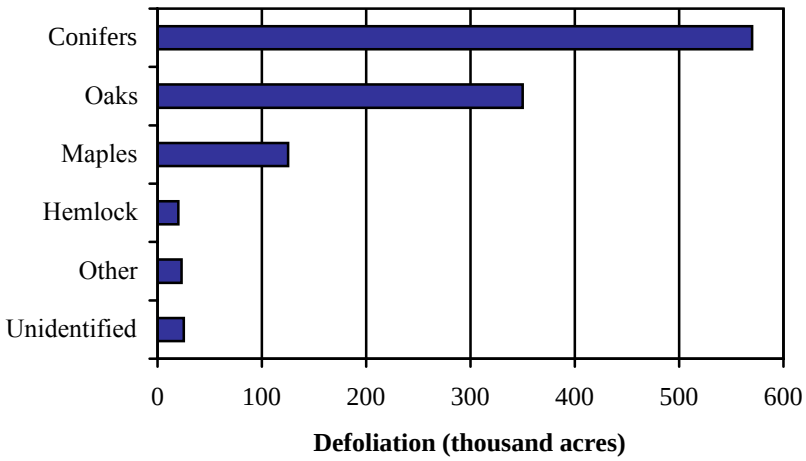

Figure 3.2. **Defoliation from native pests**.[1] In 1997, most of the defoliation from native pests occurred on oaks and various species of conifers (USDA Forest Service 1994–2002).

[1]Defoliation sources:
Conifers—spruce budworm, jack pine budworm, pine false webworm, pine shoot moth
Oaks—scarlet oak sawfly, oak leaftier, oak skeletonizer
Maples—maple leaf cutter, greenstriped mapleworm
Hemlock—hemlock looper
Other—native defoliators
Unidentified—defoliation by unidentified causes

The spruce budworm has caused extensive mortality of spruce (*Picea* spp.), balsam fir (*Abies balsamea*), and hemlock at various times in the Lake States and northern New England. In 1998, the populations in northern Maine, New Hampshire, and Vermont were at low levels although this native insect caused extensive defoliation from the mid-1970s to the early 1980s—enough that wide-scale aerial control projects were undertaken to protect the spruce-fir resource for salvage harvesting. At the same time, infestation had been significant in the Lake States. In 1998, almost 250,000 acres in Minnesota were affected and another 12,000 in Michigan. In 1999, the 46th consecutive year of spruce budworm defoliation in Minnesota, 70,000 acres were defoliated.

Oak wilt (*Ceratocystis fagacearum*) is one of the more significant diseases occurring in the Northern United States, extending from Pennsylvania to the Midwest. Various species of oak are affected. Losses in some urban areas have been substantial. The fungus spreads from tree to tree through root grafts; therefore, control measures in urban areas include trenching to sever roots between trees.

Exotic Insects and Pathogens

Since the dawn of the 19th century, exotic or introduced forest pests have had dramatic impacts on Northern U.S. forests. Of known exotics, 15 insects and 8 pathogens have had widespread impacts; many have become serious, persistent forest pests (table 3.1). Some, such as chestnut blight (*Endothia parasitica*), Dutch elm disease (*Ceratocystis ulmi*), butternut canker (*Sirococcus clavigignenti-juglandacearum*), beech bark disease, white pine blister rust (*Cronartium ribicola*), and European gypsy moth (*Lymantria dispar*), have had long-term devastating effects beyond the range of expected variation.

Table 3.1. **Introduced insects and pathogens in the Northern United States**.

Common Name	Scientific Name	Origin	Year of entry
Insects			
Elm leaf beetle	*Pyrrhalta luteola*	Europe	1834
European gypsy moth	*Lymantria dispar*	Europe	1869
Larch sawfly	*Pristiphora erichsonii*	Europe	1880
Larch casebearer	*Coleophora laricella*	Europe	1886
Beech scale	*Cryptococcus fagisuga*	Europe	1890
Pear thrips	*Taeniothrips inconsequens*	Europe	1904
Balsam woolly adelgid	*Adelges piceae*	Europe	1908
Elm bark beetle	*Solytus multistriatus*	Europe	1909
Introduced pine sawfly	*Diprion similis*	Europe	1914
Birch leafminer	*Fenusa pusilla*	Europe	1909
Hemlock woolly adelgid	*Adelges tsugae*	Europe	Prior to 1953
Common pine shoot beetle	*Tomicus piniperda*	Europe	Prior to 1992
Asian gypsy moth	*Lymantria dispar* (AGM)	Asia	1992
Asian longhorned beetle	*Anoplophora glabripennis*	Asia	Prior to 1997
Emerald ash borer	*Agrilus planipennis*	Asia	Prior to 2002
Pathogens			
Chestnut blight	*Endothia parasitica*	Asia	1904
White pine blister rust	*Cronartium ribicola*	Europe	1906
Larch canker	*Lachnellula willkommii*	Europe	1927
Dutch elm disease	*Ceratocystis ulmi*	Europe	1930
Butternut canker	*Sirococcus clavigignenti-juglandacearum*	Asia (uncertain)	Prior to 1960
Scleroderris canker	*Gremmeniella abietina*	Europe	1962
Dogwood anthracnose	*Discula destructiva*	Asia (uncertain)	Prior to 1976

Asian Longhorned Beetle

Asian longhorned beetle (*Anoplophora glabripennis*) infestations, believed to have originated on woody packing material from China, were found at a number of locations in New York (in Queens, Brooklyn, and on Long Island in Amityville and Lindenhurst) in 1996. The beetle attacks various hardwood species, causing large borer wounds in branches and stems. Infestations were also found in Chicago in 1998, with additional infested sites located in 1999. New infestations were also discovered in New York in Bayside, Manhattan, and Islip, east of Amityville. These areas were all placed under quarantine in an effort to keep the

beetle from spreading to other urban and rural forested areas. In an attempt to eradicate the beetle, about 4,000 trees were removed, chipped, and burned in the New York area. Trees were also removed in Chicago within the quarantine area. A replanting effort is underway in Chicago and New York to replace valuable street trees. Surveys continue in several States to locate any other infested areas. An extensive public awareness effort is underway to provide information on the beetle and its potential impact, and also to facilitate early detection of other infestations.

Common Pine Shoot Beetle

The common pine shoot beetle (*Tomicus piniperda*), a native of Eurasia, was first discovered affecting Christmas tree plantations in Ohio in 1992. The insect attacks a variety of pine (*Pinus* spp.) species, usually weakened trees. Over 250 counties in Indiana, Illinois, Michigan, New York, Ohio, Pennsylvania, Wisconsin, Maryland, and West Virginia have known infested sites (figure 3.3). In 1999, common pine shoot beetles were found for the first time in pheromone traps in northern Vermont and New Hampshire, and in Quebec, Canada.

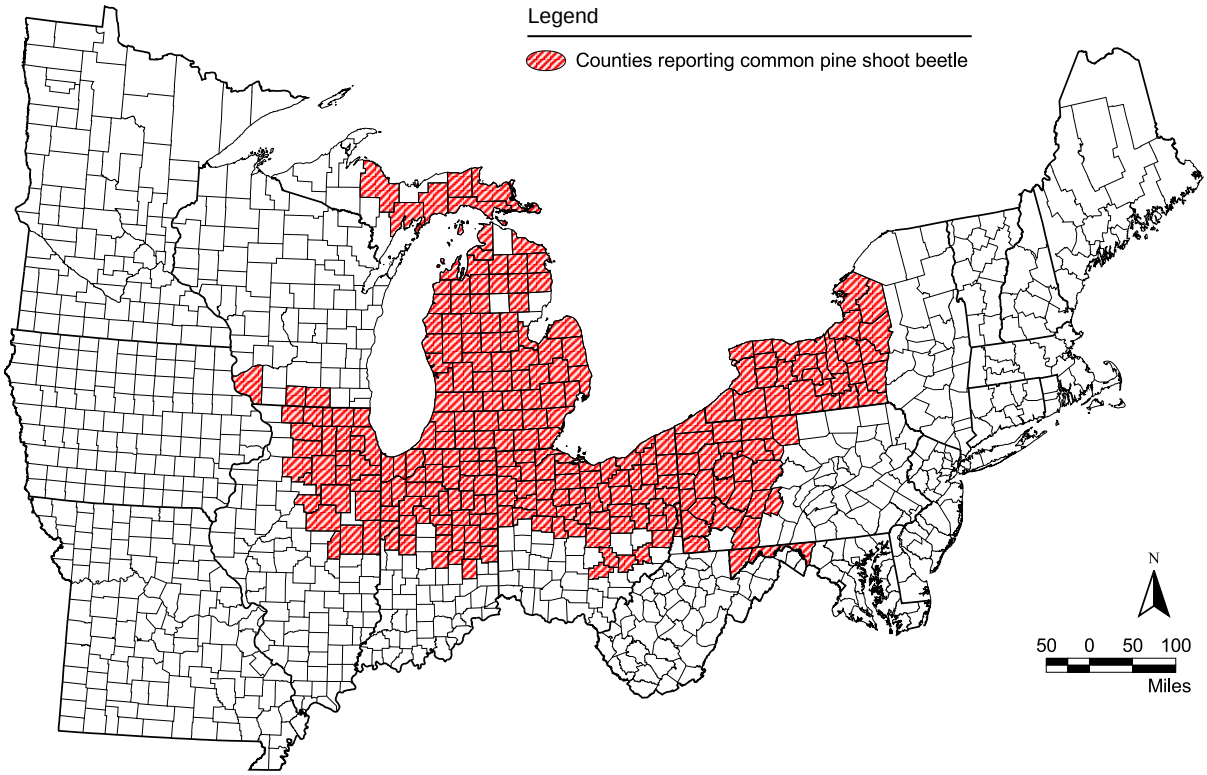

Figure 3.3. **Regional distribution of common pine shoot beetle**. In 1999, most of the occurrences of the common pine shoot beetle were located in areas around the Great Lakes (USDA Forest Service 1994–2002).

European Gypsy Moth

The European gypsy moth was first introduced into the United States in 1869. Since its accidental release in Medford, Massachusetts, the moth had spread to all or parts of 17 Northern States and the District of Columbia by 1999, and has been the most dominant invasive insect in the eastern forest. Between 1916 and 1965, the rate of spread of the gypsy moth was about 3 km per year. This rate increased to more than 20 km per year between 1966 and 1990. The movement of outdoor homeowner goods and machinery, on which gypsy moth eggs may be laid, is likely a major contributor to the spread of the insect. A "Slow the Spread" program has been initiated to deter the expansion of the range of the gypsy moth.

In 1998, over 360,000 acres were defoliated, mostly owing to the gypsy moth population explosion in Michigan, where 300,000 acres were affected. In 1999, defoliation in Michigan decreased to 176,000 acres; however, the gypsy moth increased in Pennsylvania, where 280,000 acres were affected, and Ohio, where 50,000 acres were defoliated. In New England and the Mid-Atlantic States, which have had infestations of the gypsy moth for many years, their populations are relatively low (figure 3.4).

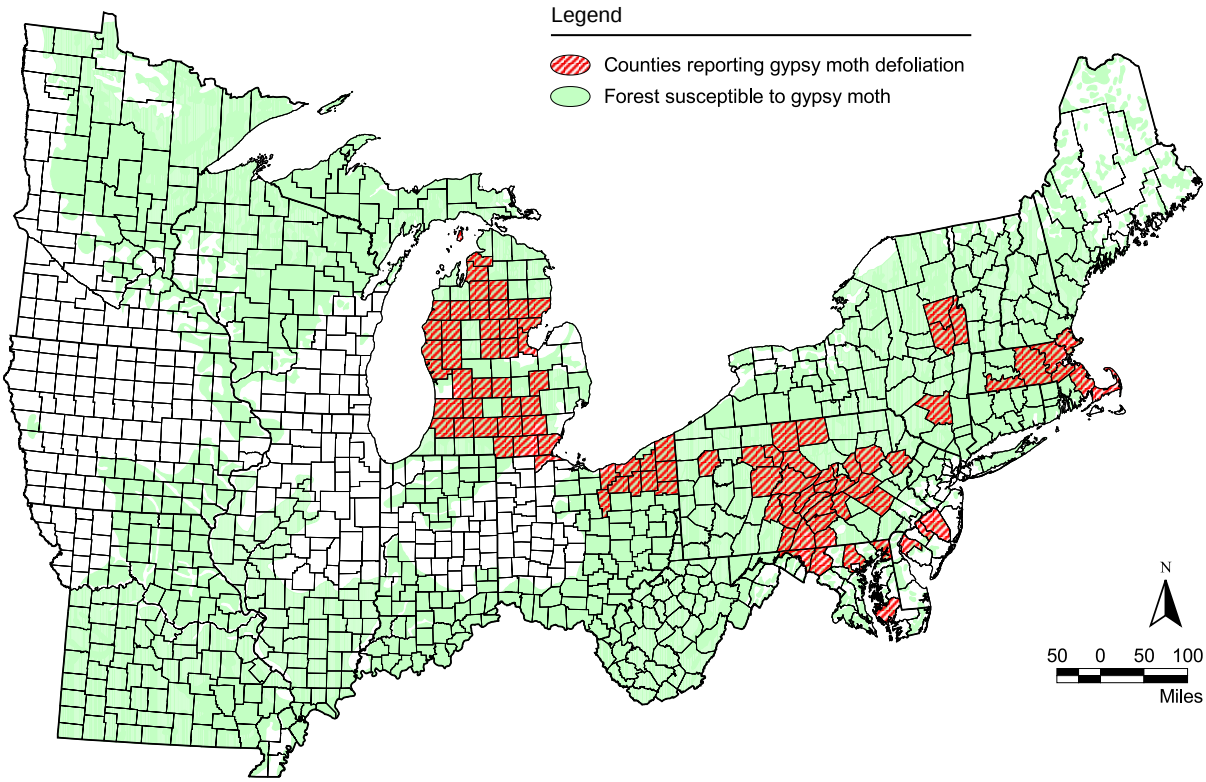

Figure 3.4. **Regional distribution of gypsy moth**. In 1999, gypsy moth defoliation occurred in Michigan, Ohio, Pennsylvania, Maryland, Massachusetts, New Jersey, and New York (USDA Forest Service 1994–2002).

The number of gypsy moth hosts exceeds 300 species of trees and shrubs, with oaks ranked among the most favored foods. The European gypsy moth currently infests approximately 25 percent of the total area of susceptible forest type in the United States. Since 1924, more than 80.6 million acres have been defoliated by gypsy moth in the Northern United States, and at the peak of its last outbreak in the early 1980s, over 13 million acres of oak forests were defoliated (figure 3.5). Gypsy moth outbreaks cause defoliation, tree mortality, and loss of recreational use of the forest owing to large numbers of caterpillars.

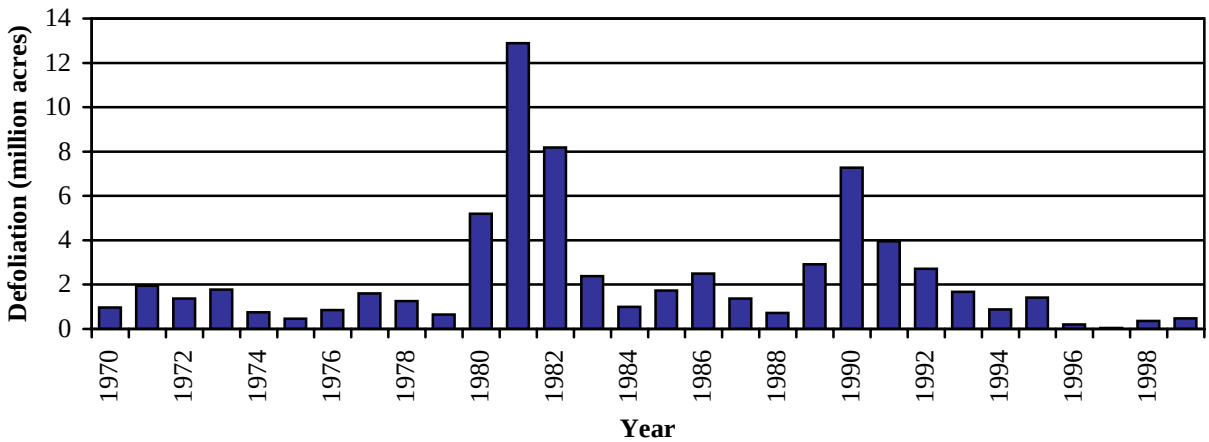

Figure 3.5. **Gypsy moth defoliation**. Prior to 1970, gypsy moth defoliation remained consistently low, averaging less than 260,000 acres per year. The highest acreage of gypsy moth defoliation occurred in 1981, when about 13 million acres were affected in the Northern United States and Virginia (USDA Forest Service 2000a).

After 2 or more years of moderate defoliation, some of the subdominant oaks may die. Mast production decreases and can continue to decrease for 5 years. Tree species favored by gypsy moth decline, leaving nonfavored species to thrive. The make-up of the forest may change, favoring more shade-tolerant species, such as red maple.

Historically, attempts to control gypsy moth populations involved chemical and biological insecticides. Many States and towns have applied insecticides by both aerial and ground application. Currently, few large-scale spray projects are conducted.

Since 1990, there has been a decline in gypsy moth defoliation. The fungal pathogen *Entomophaga maimaiga* is assumed to be responsible for the decrease in population, acting as a biological control agent. However, it may take several years of observations to determine the effects of the fungus on the population dynamics of the gypsy moth.

Hemlock Woolly Adelgid

The hemlock woolly adelgid (*Adelges tsugae*) was first reported in the Pacific Northwest in the 1920s and in eastern Virginia in the 1950s. Although little impact has been noted on western hemlock (*Tsuga heterophylla*), significant tree mortality occurred on eastern hemlocks during the 1990s. Currently, the adelgid has infested 25 percent of the 3.2 million acres of host type in 11 States extending from North Carolina to Rhode Island. Tree decline

and mortality have been reported to be heaviest in Virginia, New Jersey, Connecticut, and Rhode Island (figure 3.6). Concerns have been raised over the threat from transport of infested nursery stock into currently uninfested areas, especially into northern New England. A hemlock woolly adelgid predator beetle (*Sasajiscymnus tsugae*) was released in several States to evaluate its effectiveness at reducing adelgid populations.

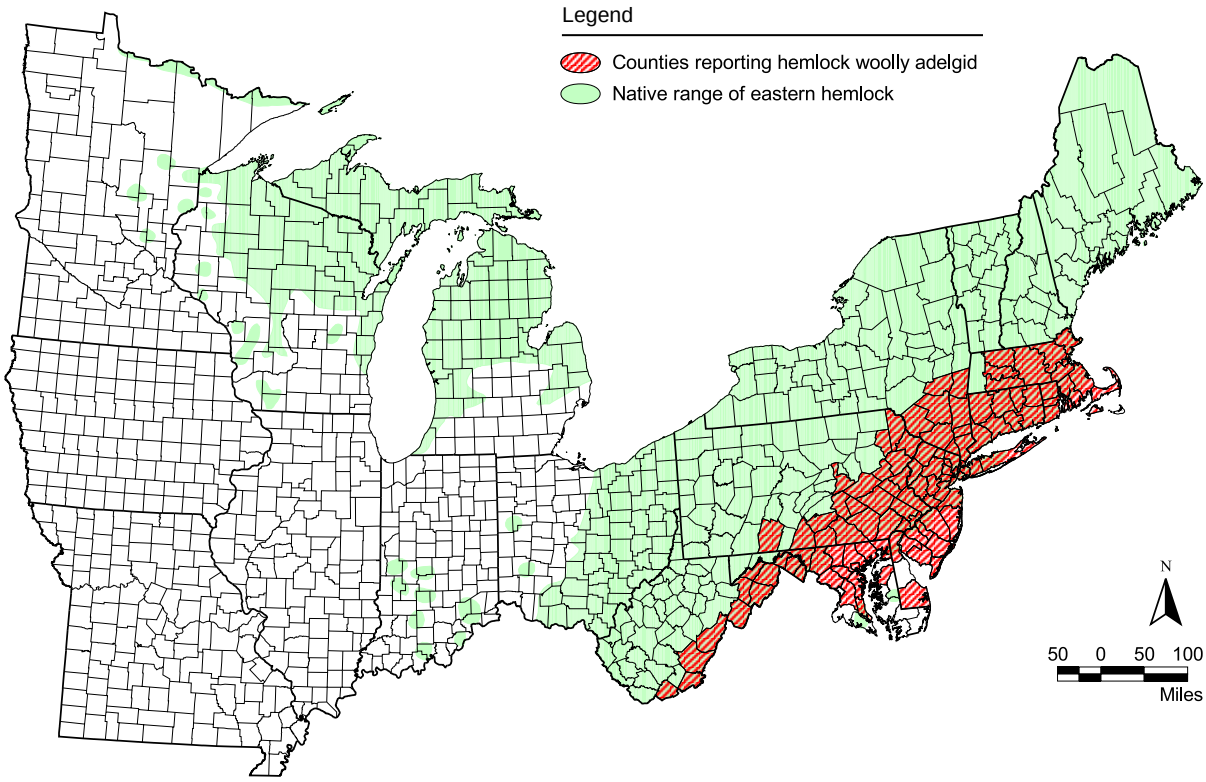

Figure 3.6. **Regional distribution of hemlock woolly adelgid**. By 1999 in the Northern United States, hemlock woolly adelgid was reported from West Virginia to Massachusetts (USDA Forest Service 1994–2002).

Beyond the obvious impact on timber productivity, the impacts on recreation and riparian and aquatic ecology are of greater concern. Recreational parks such as the Shenandoah National Park in Virginia, Devil's Hopyard in Connecticut, and Sparta Glen in New Jersey have already lost a significant proportion of their hemlock resource. The ecological concerns stem from the important functions that hemlocks provide in both aquatic and terrestrial communities. Premiere examples of these benefits include food and cover for white-tailed deer (*Odocoileus virginianus*) during the winter months and the cooling effect of the dense canopy that helps to regulate water temperature in the summer for brook trout (*Salvelinus fontinalis*) and other aquatic organisms.

Beech Bark Disease

Beech bark disease is an exotic insect-fungal complex. This disease has two components, the beech scale insect (*Cryptococcus fagisuga*) and *Nectria* fungus. The disease has spread

throughout New England into the Mid-Atlantic States from its introduction in Maine in the 1930s. Large American beech trees (*Fagus grandifolia*) have been killed by the disease and replaced by regeneration sprouts, which are also very susceptible. Today beech bark disease is evident in New England, New York, New Jersey, and Pennsylvania, with isolated pockets in West Virginia, Virginia, Tennessee, North Carolina, and possibly Ohio. This disease has changed the composition of the maple-beech-birch forests of the Northern United States and appears to be slowly spreading south and west.

Butternut Canker

Butternut canker is a fungal disease that was first identified in Wisconsin in 1967 and is now found throughout the range of the butternut tree (*Juglans cinerea*). The fungus can enter healthy trees through leaf scars or bark injury. Branch and main-stem cankers form at the site of infection. Trunk girdling can eventually kill the tree or weaken it so much that it dies from invasion by secondary organisms or windthrow.

Butternut is scattered throughout its native range. Because the trees grow in an isolated manner, questions arise as to how the inoculum can be dispersed from one isolated area to another. Occasionally healthy trees are found and cuttings or nuts are collected in an attempt to locate resistant stock. Natural regeneration in a forested setting has been difficult, because butternut is shade intolerant.

Butternut canker has caused widespread dieback and mortality and has decreased the amount of butternut by about 80 percent since 1985. Today, it is difficult to find a healthy butternut, and the species may be eliminated as a forest component. Because of this dramatic reduction, butternut is listed as a species of concern under the Federal Endangered Species Act of 1973.

Chestnut Blight

Chestnut blight essentially eliminated American chestnut (*Castanea dentata*) as an ecological and economic component of the forest. This has had at least two significant impacts. The conversion from chestnut to oak created extensive forests more susceptible to another exotic pest—gypsy moth, which prefers oak. Also, oak species that replaced chestnut were not as well adapted to sites previously occupied by chestnut.

Since the 1904 discovery of chestnut blight in New York's Bronx Zoological Park, it has spread throughout the eastern hardwood region where American chestnut once reigned. This species once occupied 25 percent of the eastern forests, but within 50 years, more than 80 percent of the region's American chestnut trees were dead and the rest were dying. Stump sprouts are still evident in some areas where the trees once grew but because the sprouts are genetically the same as the parent, they are no more resistant to the blight than are the parent trees.

The American Chestnut Foundation has been a major factor in the effort to reestablish chestnut within its native range. In addition, there have been recent advancements in the development and establishment of hypovirulent strains of the fungus. This new strain carries a virus that infects the fungus and essentially stops its growth and reproduction.

Dogwood Anthracnose

Eastern flowering dogwood (*Cornus florida*) is a common understory tree in the Eastern United States. Since the discovery of dogwood anthracnose (*Discula destructiva*) in Brooklyn in the mid-1970s, the disease has spread in a southwesterly direction, following the Appalachian mountain range. Although symptoms are more prevalent in cool, moist valleys and at elevations above 2,000 feet, the disease also can be found on woodland dogwoods and ornamentals in open landscape settings. By 1999, dogwood anthracnose had spread throughout approximately 26 percent of the natural range of eastern flowering dogwood (figure 3.7).

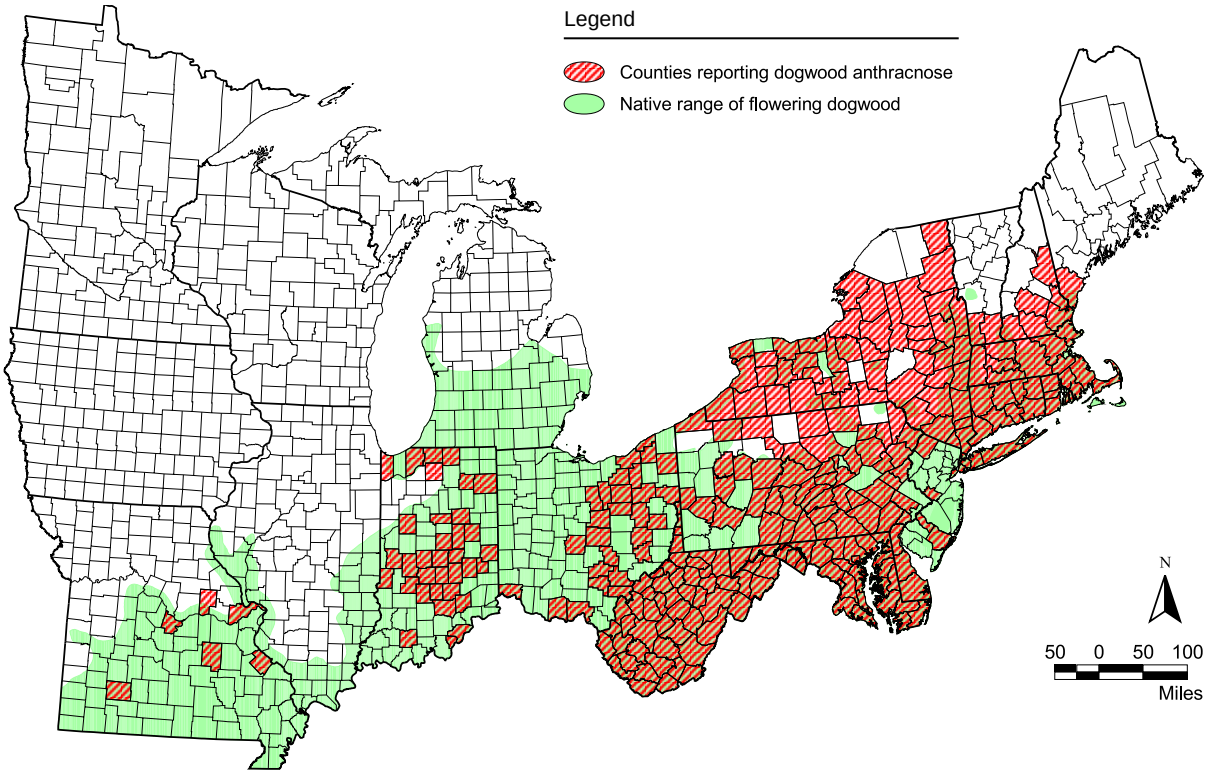

Figure 3.7. **Regional distribution of dogwood anthracnose**. Dogwood anthracnose is found from Missouri to southeastern Maine, throughout the range of flowering dogwood in the Northern United States (USDA Forest Service 1994–2002).

The sudden decline of flowering dogwood during the late 1970s to early 1980s, especially in southeastern New York, southern Connecticut, and eastern Pennsylvania, created much public concern. By the mid-1980s, State and Federal agencies began surveys to assess the distribution and impact of the disease.

From 1984 to 1994, three impact assessment studies were performed in Catoctin Mountain National Park, Maryland. By the end of the 10-year timeframe, 94 percent of the dogwoods in the survey plots were dead, and seedling regeneration in the park was almost nonexistent, given the high population density of white-tailed deer. In West Virginia, where the disease is found statewide, mortality increased from 9 percent in 1989 to 44 percent in 1999.

From field observations in southeastern New York, the impact of the disease on the population of flowering dogwoods in the Northeastern United States in the 1990s appeared to be much less severe than during the 1980s. Many landscape and roadside dogwoods recovered from earlier infection, and foliar symptoms often were limited to scattered spots and blotches. Epicormic branches and new annual cankers appeared less often.

Explanations for decreased disease severity are speculative. In woodlands, mortality of the most susceptible dogwoods possibly has left the more resistant trees. Environmental conditions may be less favorable for an anthracnose outbreak. Also a reduction in inoculum load, and interaction by competitive microorganisms on leaf surfaces are possible. In 1999, however, there was an increase in the extent of the disease in New York, where the disease was identified in 18 additional counties.

Dutch Elm Disease

Dutch elm disease has caused extensive losses of American elm (*Ulmus americana*) in both forests and urban areas since its introduction prior to 1930. The fungus was carried by elm bark beetles (*Solytus multistriatus*) on infested elm logs from Europe. An estimated 50 million elms have been killed throughout the Northern United States resulting in a loss in biological diversity and replacement costs for elms planted in urban environments. During the 1960s, there was a devastating epidemic of a new more virulent strain of Dutch elm disease. This disease has virtually eliminated American elm as a major component of forests and urban landscapes.

In an attempt to reintroduce elm trees into the urban environment, several genetic varieties of American elm have been developed. These elms are being outplanted, and will be followed over the years to determine relative resistance to the disease. A major effort in the District of Columbia involves removal, sanitation, and prevention to ensure survival of the elm population in the city. This same approach has been successful in other towns, but has high financial and labor costs.

White Pine Blister Rust

The lumber industry in the East used eastern white pine (*Pinus strobus*) for much of the 1800s and early 1900s. White pine numbers were reduced dramatically owing to exploitative logging and the introduction of white pine blister rust. In many areas eastern white pine is returning, but its extent is limited by white pine blister rust.

White pine blister rust was introduced into North America on planting stock from Europe in the early 1900s. The fungus spends part of its life cycle on *Ribes* (currant) plants. For many years *Ribes* plants were eradicated in an attempt to control the spread of the disease into nearby white pine stands. Mortality of white pine owing to blister rust is a factor in the reestablishment of white pine throughout New England and the Lake States. Pruning low branches of younger trees reduces impact when the disease is noticed early enough within a pine stand.

Currently, State agriculture and forestry agencies are debating whether to lift long-standing quarantines and allow the planting of varieties of currants that are thought to be resistant to the disease. Several studies are looking at the potential effect on the pine resource if the incidence of currants is allowed to increase.

Weather-Related Problems

Periodically, damage to forests from weather has been significant, affecting both hardwoods and conifers.

Drought

Long-term drought stresses trees and, in combination with other factors, causes a decline in individual tree health. Trees with shallow root systems, such as eastern flowering dogwood, are more susceptible to drought injury. Even in winter, if the amount of snowfall is inadequate for root insulation, the root zone may freeze or desiccate, eventually causing tree mortality. Secondary invaders such as bark beetles (Coleoptera: Scolytidae) or opportunistic fungal pathogens will further weaken and ultimately kill drought-stressed trees.

Significant droughts occurred in the Northern United States in the 1980s and 1990s. In 1999, a widespread drought from West Virginia to Maine affected various forest tree species. Foliage discoloration and premature leaf drop were prevalent on many trees, especially on ridgetops.

Ice Damage

Ice damage to trees has occurred in the Northern United States at various times. In Delaware, a significant ice event damaged hardwoods and conifers in the early 1990s. The largest ice storm in recent years occurred in January 1998 and affected approximately 17 million acres of rural and urban forests in Maine, New Hampshire, Vermont, and New York (figure 3.8). The combination of cold weather and rain resulted in an accumulation of 3 inches of ice in some areas. Communities across the four-State area qualified for emergency assistance by the Federal Emergency Management Agency, and Congress appropriated $48 million for recovery through various Forest Service programs.

The storm "footprint" covered more than 11 million acres in Maine and 46 million acres in New York. The storm damaged about 1 million acres in New Hampshire, including areas on the White Mountain National Forest. In Vermont, 951,000 acres were damaged, including portions of the Green Mountain National Forest. The damage was scattered throughout the affected area and was most severe at and above 1,800 feet in elevation.

Hardwoods, including poplar (*Populus* spp.), beech (*Fagus* spp.), birch (*Betula* spp.), black cherry (*Prunus serotina*), maple, white ash (*Fraxinus americana*), and oak, were affected much more by the storm than were softwoods such as pine, spruce, and hemlock. The storm left a substantial amount of woody debris on the ground. Debris littered roads, trails, woodlots, and maple sugaring sites. Downed trees and dangling limbs impeded access, increased fire danger, and created hazardous conditions. The trees most susceptible to bending or leaning were white birch (*Betula papyrifera*), yellow birch (*Betula alleghaniensis*), and young American beech. There were stands where patches of beech and birch with intact crowns were bent to the ground.

Overall, the ice storm caused a significant forest disturbance. Various-sized openings were created, and many trees were severely impacted. There will probably be increased decay and dieback, and reduced vigor in heavily damaged areas for a few years. Excessive epicormic

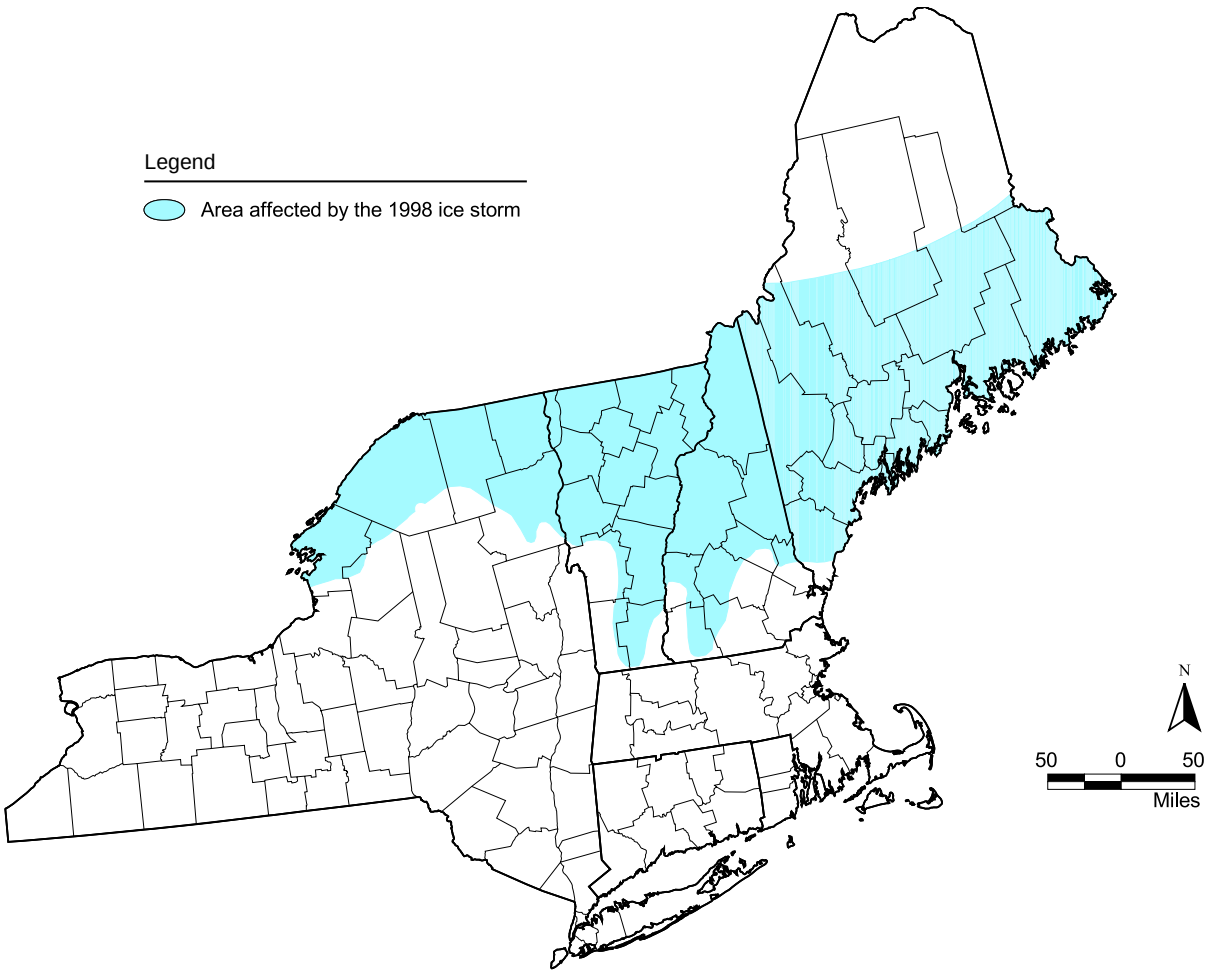

Figure 3.8. **Area affected by the 1998 ice storm**. The January storm affected an estimated 17 million acres in New York, Vermont, New Hampshire, and Maine (Miller-Weeks and others 1999).

branching is occurring on larger branches and broken trunks, especially on beech, maple, and cherry. Changes in species composition may occur over time. Long-term monitoring will document the resilience of the northern forest.

Wind Damage

In 1998, significant wind damage occurred throughout the Northern United States. Almost 300,000 acres were affected by windstorms in Wisconsin, and about 30,000 acres were severely damaged in Iowa. Storms toppled trees on 83,000 acres in New York and 30,000 acres in Minnesota. In 1999, extensive tree breakage and blowdown also occurred on approximately 460,000 acres in northern Minnesota, including the Boundary Waters Canoe Area Wilderness. Areas of Wisconsin, New York, and Vermont also were damaged by severe storms. It will take many years for the affected forest stands to recover from the extensive crown damage, stem breakage, and blowdown.

Forest Management Practices

During the last 50 years, two forest management practices have had dramatic effects on the northern forest—selective harvesting and fire suppression.

Selective Harvesting

Throughout the Northern United States, a preference for logging the biggest and most valuable oak has resulted in significant species composition changes, with oak being replaced by maple in many areas. Throughout New England and the Mid-Atlantic States, oak volume removed has accounted for 40 to 60 percent of total hardwood volume removed.

Fire Incidence and Suppression

In the Northern United States, wildfires consume approximately 210,000 acres annually (figure 3.9, appendix 3–A). Unlike the West, where it is common to have large wildland fires that receive national news coverage, most fires in the Northern United States are small. Several larger fires have occurred here recently, however, including Mack Lake, Michigan, in 1980 and Long Island, New York, in 1995. The incidence of fire depends on weather, ignition sources, and fuel types. Natural fires are cyclic and necessary to maintain forest health, for example, in the Pine Barrens of the Atlantic coastal region and in the jack pine (*Pinus banksiana*) forest of the Lake States. But fires can present a hazard to the human population. A recent study of the Northern United States indicated that about one-half of the area was of moderate to high hazard, based on population, fuels, and topography.

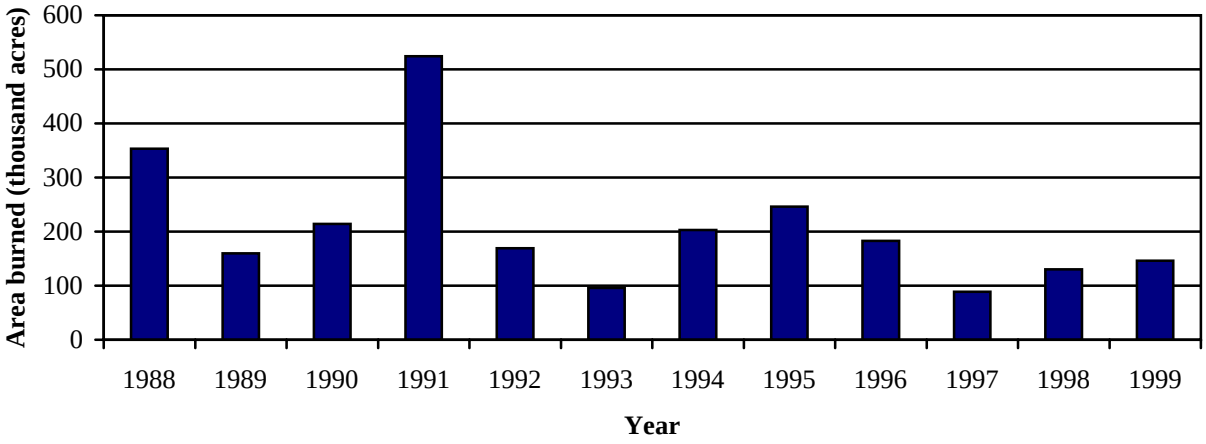

Figure 3.9. **Acres burned by wildfires**. Between 1988 and 1999, an average of about 210,000 acres burned annually in the Northern United States.

Major fires in the East and the West are caused by different factors. Lightning, a major ignition source in the West, accounts for only 1 percent of the fires in the Northern United States. Arson and debris burning account for 75 percent of the fires in this area. As in most areas of the country, 1997 was a low fire year in the Northern United States. Only 88,876 acres were scorched, which was the lowest figure during 1988–1997. In comparison, both 1987 and 1991 were very active fire years, with over half a million acres consumed. Also, 1,875 fires burned over 84,000 acres in West Virginia in 1999.

Fire influences the forest composition. Oak species are more fire tolerant than maples, and fire suppression activities tend to favor maple forests over oak.

Special Issues

Maple Mortality

In the late 1970s, maple syrup producers and land managers in the northern hardwood forests of New York and Pennsylvania began noticing that the sugar maples appeared unhealthy. In 1994, a survey from seven Pennsylvania counties reported 11.9 percent maple mortality. Questions arose as to why the maples were declining.

Several factors have been associated with the decline of sugar maples in New England, New York, and Pennsylvania. Between 1991 and 1994, many hardwood species, predominantly sugar maple, were severely stressed by feeding of elm spanworm (*Ennomos subsignarius*). During summer 1994, forest tent caterpillars defoliated 800,000 acres and fall cankerworm defoliated 230,000 acres of eastern hardwoods, of which sugar maple was a primary component. In the 1990s, pear thrips (*Taeniothrips inconsequens*) were responsible for damaging maple buds in spring. Maple anthracnose (*Gloeosporium* spp.) is caused by a fungus that infects emerging leaves during the early spring. If environmental conditions are favorable, symptoms will intensify as the leaves mature and eventually drop off. As a consequence of loss of leaves, trees will have reduced starch reserves in their roots that may affect growth and vigor.

Invasive Plants

Of the thousands of exotic plant species, 94 taxa are officially recognized as Federal noxious weeds. Invasive plants are estimated to occupy well over 100 million acres, and the populations are predicted to increase by 8 to 20 percent annually.

When invasive plants colonize a clearcut area, they compete with forest seedling regeneration. They also displace native plant species and disrupt wildlife habitat. Mile-a-minute weed (*Polygonum perfoliatum*), an import from Asia, forms dense mats and suppresses seedling growth. As its name implies, it is capable of growing very rapidly in sunny locations. This invasive weed has established in New York, Pennsylvania, Maryland, Delaware, Virginia, West Virginia, Ohio, and the District of Columbia. It can be found along roadsides, streambanks, clearcuts, and other disturbed areas. Another species, *Polygonum cuspidatum,* commonly known as Japanese knotweed, will aggressively invade a clearcut area once it is established. The spreading and tenacious rhizomes are almost impossible to remove.

The kudzu vine (*Pueraria lobata*) was intentionally introduced in the 1930s. The USDA Natural Resources Conservation Service (formerly the Soil Conservation Service) distributed 85 million kudzu seedlings to southern landowners. Since kudzu is a legume and fixes nitrogen, it was used as a soil enricher and stabilizer. The high protein content also was found to benefit livestock. By the 1950s, however, kudzu was considered a nuisance species, and it had infested almost 7 million acres in the Southeast by 1991. Kudzu has since spread northward and in 1999 was found in West Virginia, Maryland, Pennsylvania, and Delaware.

Exotic plants are not the only ones capable of being invasive. New York fern (*Thelypteris noveboracensis*) and hayscented fern (*Dennstaedtia punctilobula*) are both natives, but white-tailed deer do not eat them. These ferns are highly invasive in clearcut areas in Pennsylvania, West Virginia, New York, Maryland, and Ohio, making seedling and sprout regeneration of desirable species nearly impossible.

Deer Browsing

Concerns over the increasing white-tailed deer population in the Eastern United States and its effects on forest sustainability have been the subject of many scientific articles (Warren 1997). Numerous studies have documented the effects of deer on plant species composition, community structure, and regeneration for many forest types (Stromayer and Warren 1997). Two regions of the Northern United States have been intensively studied—the Allegheny Plateau and the Great Lakes States.

Studies in the Allegheny Plateau indicate that deer browsing has profound effects on establishment of regeneration, species composition, and density of hardwood seedlings (Horsley and Marquis 1983; Marquis 1974, 1981). In the Great Lakes States, studies on the effects of deer browsing have documented a replacement of conifers (e.g., hemlock, Atlantic white cedar [*Chamaecyparis thyoides*], and Canada yew [*Taxus canadensis*]), by hardwoods (Alverson and others 1988). Effects of deer browsing in other areas in the East include the decline of Atlantic white cedar in the New Jersey pine region (Little and Somes 1965) and suppression of balsam fir in West Virginia (Michael 1992).

The problem appears to be too many deer. According to Jones and others (1993), the white-tailed deer has made a remarkable recovery throughout its range since being hunted to near extinction in the late 1800s to early 1900s. Protective game laws, freedom from natural predators, and an abundance of early-successional habitat producing large quantities of food were the likely triggers for this explosion.

High deer populations were described in relation to three types of carrying capacities:

- **Cultural**—the maximum number of deer that can coexist compatibly with local human populations
- **Biological**—the number of deer the ecosystem can support in good physical condition over an extended period of time
- **Biological diversity**—the maximum number of deer that can exist without negatively affecting floral and faunal diversity

Biodiversity carrying capacity is exceeded at lower deer densities than either cultural or biological carrying capacities.

Plant species may be reduced or eliminated when deer numbers exceed biodiversity carrying capacity. Deer densities exceeding 20 per square mile produce negative impacts on forest regeneration or sustainability, understory plants (ferns, flowers, and shrubs), biodiversity, and wildlife.

Numerous exclosure studies in Pennsylvania indicated that deer can affect forest regeneration by reducing the height and density and changing the species composition of seedlings and sprouts (Marquis and Brenneman 1981). Excessive browsing accounted for many of the regeneration failures and has virtually eliminated understory growth in many timbered stands. Species most desirable for timber production in Pennsylvania include black cherry, sugar maple, red maple, white ash, and northern red oak, but they are also the most desirable species preferred by deer.

Deer also often remove advance regeneration, which is usually the most important factor in satisfactory regeneration following a final harvest cut. The effects of deer on forest resources also depend on the surrounding landscape, and are a function not only of deer density but also of forage availability (DeCalesta and Stout 1997). For example, in areas with high amounts of deer food in the surrounding area, fewer deer effects are likely than in areas with low amounts of deer food in adjacent areas.

Understory plants are affected by deer browsing in a manner similar to tree seedlings at deer densities exceeding 20 per square mile. That is, some species are eliminated, others are reduced in abundance and size, and plant composition changes. The usual result is fewer shrubs and wildflowers, and more less-palatable species such as ferns, grasses, and sedges. Although the park-like or barren appearance of the forest floor is pleasing to some, species richness suffers.

Excessive deer browsing also affects other wildlife. Some of the effects include reduced nesting sites for songbirds, changes in composition of small mammals, reduced winter food for turkeys (*Meleagris gallopavo*), and less protective cover for black bear (*Ursus americanus*) and ruffed grouse (*Bonasa umbellus*) (Jones and others 1993). Species richness and abundance of intermediate-canopy songbirds decreased along with nesting and foraging habitat for these birds in a Pennsylvania study (DeCalesta 1994).

One of the biggest effects of excessive deer browsing is on biological diversity, which includes all of the above (tree seedlings, shrubs, wildflowers, songbirds, and small mammals). The concept of biological diversity is important to the national Forest Stewardship Program, which encourages private nonindustrial landowners to practice responsible forest-resource management. The values of species include intrinsic, economic (food, medicine, clothing, shelter, tools, trinkets, fuel, recreation, services), spiritual, scientific and educational, ecological, and strategic (Hunter 1996).

Measures to help alleviate the deer browsing problem include fencing, tree shelters, and habitat management (i.e., providing lots of forage). These are short-term, costly fixes. In the long term, bringing the herd under control with the informed consent of landowners, legislators, hunters, and the general public may be the best solution.

Forest Health Monitoring Program

The Forest Health Monitoring Program began in the Northeastern States in 1990 and in the North Central States in 1994. In 1999, 18 of the 20 Northern States were in the program; Iowa and Ohio were added in summer 2000. The objective of the program is to monitor, assess, and report on the long-term status and changes in forest health. This is accomplished through assessing tree conditions, soil characteristics, lichens, and air quality on permanent plots established throughout the region.

Northeastern States

In 1998, the health of 135 forested plots was monitored in the Northeastern States (table 3.2). These plots included 3,149 trees, 970 saplings, 4,860 seedlings, and 410 standing dead trees. The most frequently encountered species of trees greater than 5 inches d.b.h. were maple, spruce-fir (*Abies* spp.), birch, and oak (figure 3.10). Maple and spruce-fir also made up the majority of smaller trees (saplings and seedlings), along with oak and beech. Plots were newly established in New York in 1999.

North Central States

Across the North Central States, the health of 131 forested plots was monitored in 1998 (table 3.2), which included 3,060 trees, 569 saplings, 3,482 seedlings, and 387 standing dead trees. As in the Northeastern States, maples were the most predominant trees encountered (figure 3.10). Softwoods, including spruce, fir, red pine (*Pinus resinosa*), and other softwoods, made up about one-quarter of the trees on the plots. Aspen was also a significant component. In the smaller saplings and seedlings, maple, spruce-fir, aspen, ash, oak, and other hardwood species were predominant.

Table 3.2. **Land cover of Forest Health Monitoring plots in the Northern United States, 1998**.

State	Forested plots	Nonforested plots
Northeastern		
Connecticut	2	3
Delaware	—	4
Maine	41	4
Maryland	6	3
Massachusetts	7	4
New Hampshire	11	2
New Jersey	3	7
Pennsylvania	28	25
Rhode Island	—	1
Vermont	9	3
West Virginia	28	2
Total	**135**	**58**
North Central		
Illinois	12	61
Indiana	10	37
Michigan	45	32
Minnesota	30	57
Wisconsin	34	38
Total	**131**	**225**

Crown Conditions

One of the primary indicators of tree health is the condition of foliage. Several crown conditions are measured for each tree, including crown density, dieback, and foliage transparency. Crown density is the amount of branches and foliage that blocks light visible through the crown. Dieback assesses the recent mortality of branches and twigs in the outer crown. Foliage transparency is a measurement of the amount of light visible through the live crown. High transparency, which is an indication of a thin crown, can result from defoliation, disease, or stress.

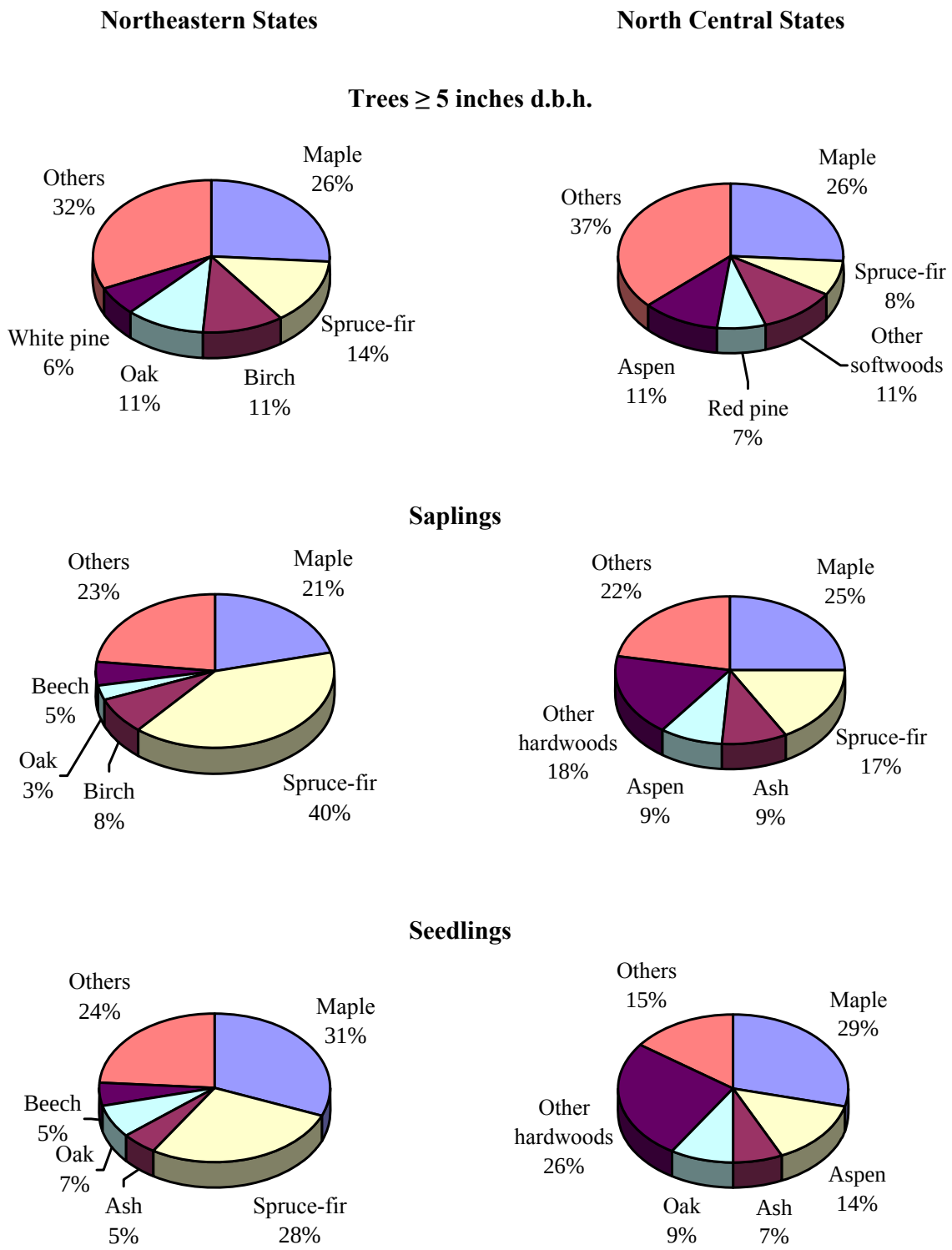

Figure 3.10. **Distribution of tree species on Forest Health Monitoring plots**. Maple, birch, oak, aspen, white pine, red pine, spruce, and fir are the most frequently encountered tree species on Forest Health Monitoring plots in the Northern United States.

In 1998, 97 percent of all hardwood and softwood trees measured in the Northeastern States were observed to have normal crown conditions in terms of foliage transparency, crown density, and crown dieback. This observation is consistent with Forest Health Monitoring ratings from previous years. Maples had the highest number of trees with poor crown conditions, although the proportion was not significant. Of the 825 maples observed, only 22 (3 percent) had poor crown density, and 31 (4 percent) had moderate to severe dieback.

In the North Central States, 96 percent of the trees had normal crown conditions. As in the Northeast, maples had the highest number of trees with poor crown conditions. Of 808 trees measured, 19 had poor crown density and 27 had moderate to severe dieback—only about 2 to 3 percent of the trees.

Dead Trees

In 1998, 410 standing dead trees were recorded on plots in the Northeastern States and 387 on North Central plots. These standing dead trees represent cumulative mortality as the trees may have died recently or years ago. Dead trees represent 12 percent of the total trees observed on Forest Health Monitoring plots in the Northeast and 11 percent in the North Central States.

Damage

Of the 3,149 trees measured in the Northeastern States in 1998, 24 percent had observable damage—20 percent had one type of damage, 3.8 percent had two, and 0.5 percent had at least three types of damage. In general, the most frequently reported types of damage on all trees were indications of decay, loss of apical dominance, and open wounds. The species groups with the highest percentage of trees with observable damage were walnut (*Juglans* spp.), maple, birch, basswood, and sweetgum (*Liquidambar styraciflua*) (table 3.3).

Table 3.3. **Species with greatest damage on Forest Health Monitoring plots in the Northern United States, 1998**.

Species	Trees sampled		Damage observed
	Percent	Number	
Northeastern States			
Walnut	55	9	Vines, cankers, and seams
Maple	32	825	Decay, loss of apical dominance
Birch	33	332	Decay, cankers
Basswood	36	14	Vines, decay
Sweetgum	35	20	Vines, decay
North Central States			
Walnut	42	19	Vines, loss of apical dominance
Maple	38	808	Decay, canker
Basswood	37	59	Decay

Of the 3,060 trees measured in the North Central States in 1998, 27 percent had observable damage—21 percent had one type of damage, 4.9 percent had two, and 1.3 percent had at least three types of damage. The species groups with the highest percentage of trees with observable damage were walnut, maple, and basswood (table 3.3). The most frequently reported damages on all trees in 1998 were indications of decay, loss of apical dominance, cankers, and cracks/seams.

Indicator 16. 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

Abiotic Stress—Air Pollution

Significant threats to the forest ecosystem come from exposure to ozone and acid deposition. The production of atmospheric ozone is catalyzed by photochemical reactions with hydrocarbons and oxides of nitrogen. As polluted air drifts, ozone is concentrated in areas far from where the pollutants are generated. For this reason, ozone is considered a regional pollutant. Bioindicator plants that are sensitive to ozone damage are monitored annually as part of the USDA Forest Service Forest Health Monitoring Program. In 1999, ozone-induced foliar injury was detected on many of the biomonitoring sites (figure 3.11).

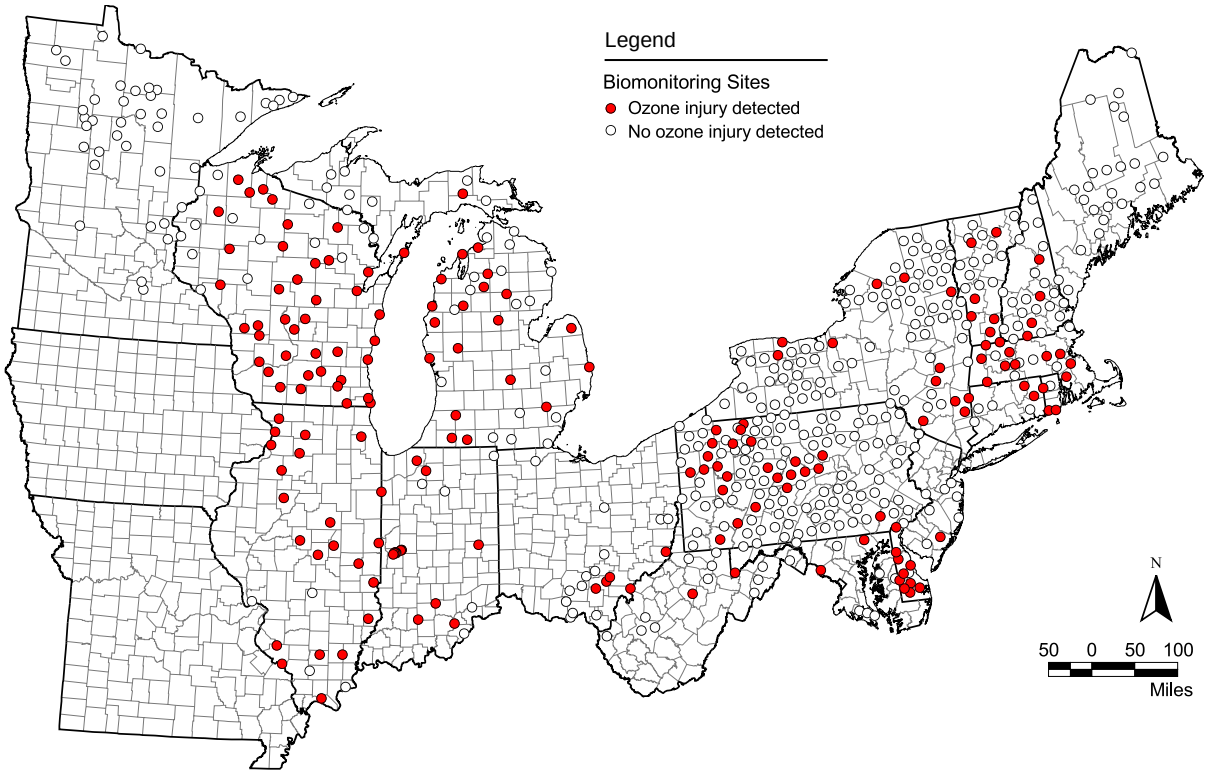

Figure 3.11. **Ozone injury detected, 1999**. Ozone injury was detected on some of the biomonitoring sites associated with Forest Health Monitoring plots across the Northern United States.

Sulfur dioxide is emitted into the atmosphere by activities such as burning fossil fuels, smelting ore, and manufacturing steel. Sulfur dioxide and hydrogen fluoride are both considered point source pollutants and damage trees immediately downwind from the production source. Certain tree species have been shown to be more susceptible to ozone, whereas some species seem to be quite tolerant. Susceptibility varies even within species, such as white pine, where "chlorotic dwarfs" and mortality are the result of ozone sensitivity.

Trees growing in highly buffered soils tend to be more tolerant of the effects of air pollution fallout. Sulfur and nitrogen oxide deposition may have an effect on soil chemistry in the unglaciated oak-hickory region, where soils tend to have a low buffering capacity. In the Northern United States, the usual pH of rainwater is 5.6; since the mid-1980s, collected rainfall averaged pH 4.3. This has contributed to the concern over acid rain.

Acid deposition has contributed to a regional decline in available calcium in spruce-fir forests in New York and New England through two mechanisms—leaching of calcium from the root zone and mobilizing aluminum, which blocks calcium uptake. These changes have resulted in impaired mineral nutrition in some areas. Acid deposition has also reduced cold tolerance of high-elevation red spruce (*Picea rubens*) in the Northern United States resulting in frequent winter injury to current foliage. Acid deposition has also been suspected to contribute to extensive areas of maple mortality on some soils in Pennsylvania and New York.

In response to concerns about the status of the maple resource and possible effects from acid deposition, the North American Maple Project (NAMP) was formed in 1987 to annually visit selected sugarbush and forest maple stands (see figure 7.11). The project has been administered jointly by the Canadian Forest Service and the USDA Forest Service, and has involved 10 States and 4 Provinces. The objectives are to look at the rate of change in maple condition, to determine if change is related to various levels of acid deposition, and to ascertain possible causes of any tree decline. The long-term data set provides information on tree condition and mortality over the years (Allen and others 1995).

In 1998, 230 NAMP sites were monitored in both sugarbush and forested stands. A total of 13,481 sugar maple trees were observed, of which 9,359 were overstory trees. The average basal area of the stands was approximately 115 ft^2/acre. The trees were evaluated for crown condition and tree damage. The average dieback of the overstory trees was about 8 percent. The overall crown condition has improved over the years, in the absence of significant maple defoliators such as pear thrips, forest tent caterpillar, and maple webworm. In 1998, over 94 percent of the trees in most areas had healthy vigorous foliage. Annual mortality ranged from 0.3 to 1.7 percent in the overstory trees, with an average 0.7 percent per year since 1989. This is within the expected normal range of annual mortality for sugar maple. There were slight increases in mortality from the January 1998 ice storm.

Indicator 17. 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

There is not enough information readily available to address this indicator at this time.

Summary and Conclusions

Forest health is a term that describes forest condition in relation to values, needs, and ecosystem functions. The general health of the forest is difficult to assess at any one time, as it is dynamic and undergoing constant change. Measures of forest health include the age and composition of the forest, trends in tree growth and mortality, tree crown condition, vulnerability to forest health stressors and frequency of occurrence, and the condition of soil, water, and wildlife.

Stressors that affect tree health include insect, pathogen, and plant pests; herbivores; severe weather; global climate change; and air pollution. The major threat from forest pests in the Northern United States is from nonnative, or exotic, insects and pathogens. Recent exotic insect introductions include the hemlock woolly adelgid, common pine shoot beetle, and Asian longhorned beetle. These introductions have prompted the establishment of quarantines and eradication efforts. Invasive plants, such as mile-a-minute and Japanese knotweed, are becoming a concern, as they colonize and become competitive with forest seedling regeneration. Invasive plants can also displace native plant species, which can have an effect on wildlife habitat.

Increasing white-tailed deer population in the eastern United States affects forest sustainability and has impacted plant species composition and community structure. Abiotic factors, including drought, ice storms, wind, and fire have also historically caused significant damage in the Northern United States. Significant threats to the forest ecosystem also come from the exposure to atmospheric ozone and acidic deposition.

Combinations of stressors, such as exotic insects and pathogens along with drought, cause the greatest impact. Various stressors can result in a decline in forest stands from tree dieback and deterioration. Annually monitoring the forests of the Northeast, through the Forest Health Monitoring Program and other State/Federal cooperative forest health surveys, provides valuable information on the status and trends in forest health caused by the various stress factors.

Appendix 3–A. Acres burned by wildfires, by State, 1988–1999

State	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CT	3,241	2,782	1,279	1,679	489	349	1,049	473	94	611	13,515	1,733
DE	1,482	556	784	539	37	415	57	418	72	510	97	231
IL	2,742	6,605	5,743	7,491	3,346	3,242	6,207	6,070	5,447	1,078	2,627	3,570
IN	3,052	632	697	604	1,435	1,893	17,093	25,934	12,320	2,426	2,415	11,711
IA	16,075	3,671	2,551	5,700	3,560	7,782	8,289	4,446	1,751	4,261	16,075	3,560
ME	2,668	2,403	837	3,098	4,531	1,640	2,024	1,165	419	795	1,533	1,066
MD	8,508	3,500	3,515	8,249	2,881	2,802	2,020	5,376	1,082	1,833	2,052	2,935
MA	7,205	3,382	4,612	4,253	5,207	5,250	7,631	8,263	2,221	4,456	3,158	7,603
MI	8,049	4,566	9,157	1,472	1,976	903	5,040	4,395	2,100	1,400	4,888	8,228
MN	170,736	28,803	96,385	51,920	83,560	31,952	20,176	21,907	17,966	16,447	35,584	16,675
MO	52,303	47,396	44,180	75,991	27,639	18,293	52,012	55,713	123,889	29,143	9,306	18,720
NH	587	556	488	296	347	224	2,762	458	89	177	156	430
NJ	3,565	6,758	2,637	4,256	16,650	2,667	3,018	22,583	1,009	4,928	1,477	16,440
NY	5,031	11,730	1,589	3,394	2,007	623	1,176	8,546	213	1,218	1,678	5,437
OH	8,259	3,226	1,666	2,769	2,878	2,805	7,985	6,594	2,486	4,698	4,019	6,010
PA	6,803	9,527	15,407	3,743	1,926	3,318	4,537	3,459	1,712	4,022	6,015	6,079
RI	564	254	137	269	81	227	452	120	136	120	192	182
VT	516	418	389	747	719	354	386	439	151	236	441	274
WV	42,156	18,915	14,964	346,197	7,625	10,024	56,286	42,540	6,725	8,030	3,964	3,510
WI	9,740	4,184	7,288	1,756	2,515	1,365	4,317	27,116	2,859	2,487	21,233	31,462
Total	**353,282**	**159,864**	**214,305**	**524,423**	**169,409**	**96,128**	**202,517**	**246,015**	**182,741**	**88,876**	**130,425**	**145,856**

Criterion 4

Conservation and Maintenance of Soil and Water Resources

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Criterion 4. Conservation and Maintenance of Soil and Water Resources

Constance Carpenter,[1] Al Todd,[2] and Karen Sykes[3]

Soil and water provide the basic foundation for all other resources in the forest.

Soil is a natural resource that is nonrenewable when viewed on human time scales. Soil has living and nonliving components and a unique developmental history. 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 creatures. The organically enriched biologically active portions of the soil transform nutrients and pollutants, thus contributing to a healthy environment.

Water is abundant in the Northern United States. **Water resources** include the physical features, habitat, and inhabitants of lakes, streams, wetlands, and riparian areas as well as the water itself. The Northern United States was endowed by nature with many inland lakes, streams, headwaters, and wetlands. In 1997, water bodies and streams in permanent open water covered roughly 15 million acres of the Northern United States. Wetlands and deepwater habitats on water and non-Federal land total over 41 million acres (USDA NRCS 2000).

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—touch the northern border of the Northern United States. With good reason, Minnesota is called the land of 10,000 lakes. The Eastern States are bordered by Atlantic coastal bays and estuaries. Notable features include the Chesapeake Bay, Delaware Bay, Long Island Sound, Massachusetts Bay, Casco Bay, and Penobscot Bay.

In addition to surface waters, the area has extensive groundwater resources. Bedrock aquifers are prevalent at varying depths throughout the Northern United States. Ancient sand lenses are a source of groundwater in the Midwest and coastal plains. Aquifers in glacial deposits are common in the northern portions of the region.

Water resource quality is often assessed on a watershed basis. A **watershed** is a geographic land area within which water flows to a common point (figure 4.1). Watersheds are bounded by ridges that catch rain and snow, and drain into a marsh, stream, lake, estuary, or groundwater aquifer. Small watersheds nest within larger watersheds. Large watersheds contain a stream network. Water usually enters a watershed through precipitation and leaves as streamflow, groundwater discharge, evaporation, or transpiration. Soil, vegetation, topography, climate, land use, and wildlife are important factors that affect watershed

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functions, water quality, streamflow, flooding, and aquatic life. Forests as part of the earth's hydrologic cycle play an especially important role in the regulation of surface and groundwater flow and quality.

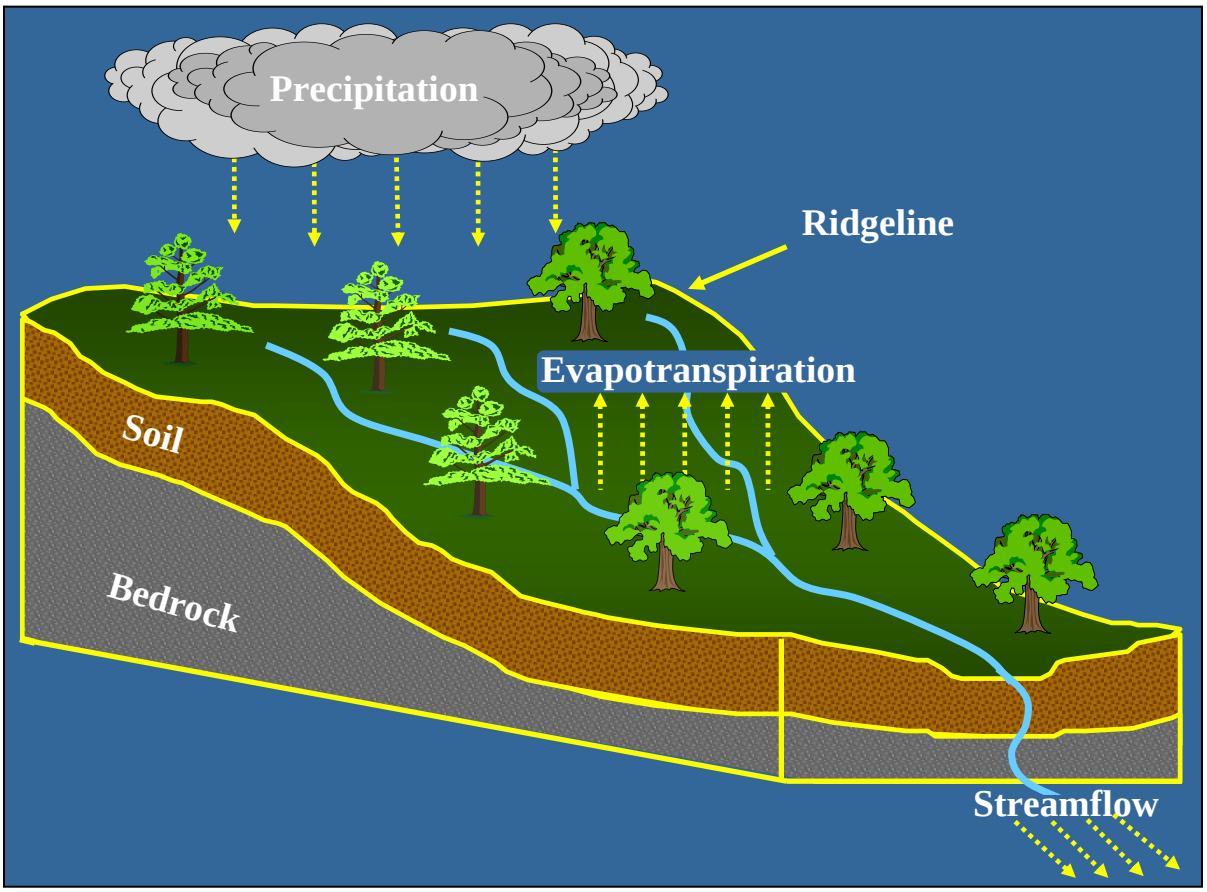


Figure 4.1. **What is a watershed?** A watershed is an area of land, bounded by ridgelines, that catches rain and snow and drains into a marsh, stream, lake, estuary, or groundwater aquifer.

Forested watersheds are important for storing water and providing for its long-term release and groundwater recharge. They are the source of approximately 66 percent of the total national water yield. Forests help sustain **watershed functions** (figure 4.2). Trees and forests help reduce stormwater runoff; filter pollutants from air and water; store water and nutrients; protect soils, floodplains, and streambanks; clean and cool air and water; protect municipal water supplies; reduce flooding; recharge groundwater aquifers; and provide critical fish habitat. Forests adjacent to bodies of water buffer the movement of pollutants from upslope land use activities and support aquatic health through regulation of temperature, additions to the food web, and provision of habitat structure. The amount, location, and management of forest land in a watershed are important to the quantity and quality of water in streams, lakes, wetlands, and groundwater aquifers. Clean water is one of the most important forest products.

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

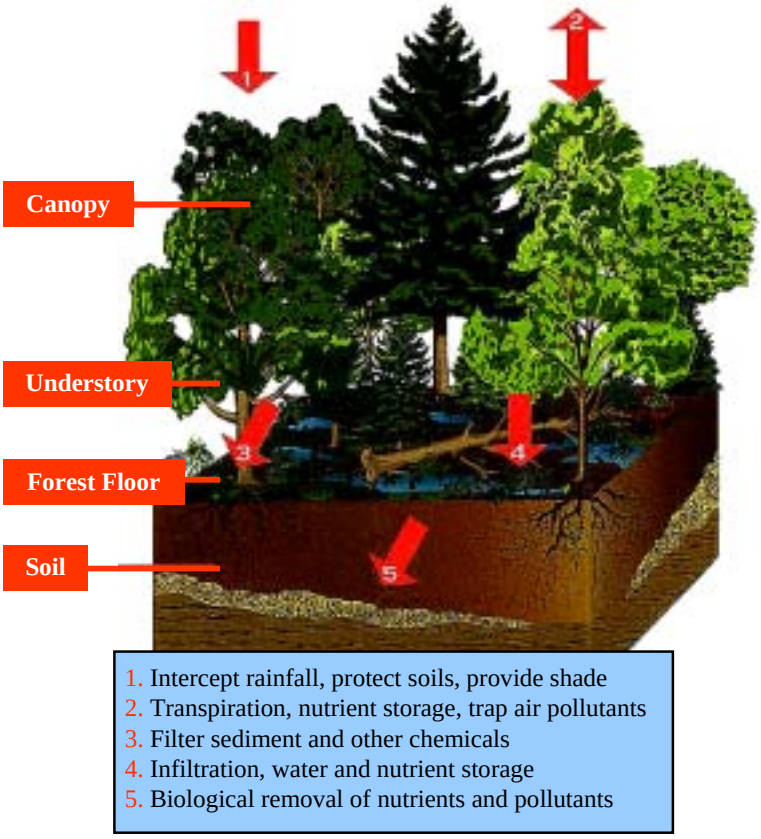


Figure 4.2. **Forest functions**. Physical, chemical, and biological processes in forests are key to sustaining water quality and supply, and watershed health.

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 are as likely to be the result of activities or natural disturbances that affect the land and vegetation of a watershed or aquifer recharge area, as they are to be the result of activities, like point source pollution or overfishing, that directly impact the physical or chemical nature of the water resource or the biota.

Most watersheds contain a mosaic of land uses that include forests. Forest management has comparatively less effect on water quality than agriculture, urban development, and most other human land uses, although poorly planned forestry activities have the potential to degrade water resources. In the Northern United States, many forests, historically managed for forest products, are intermingled with farmland and pasture, and increasingly with suburban development.

Indicator 18. Area and percent of forest land with significant soil erosion

Soil erosion occurs when the rate of soil loss from a site is greater than the rate of soil formation. The loss of soil, especially topsoil, the most nutrient-rich, biologically active portion of the soil, inevitably influences the productivity, vitality, and species composition of forest ecosystems. In an undisturbed forest, the soil is shielded from rain by the tree canopy and covered by a protective layer of organic material. The porous surface layers of forest

soils maintain rates of infiltration far in excess of usual rainfall intensities, reducing runoff that increases the potential for erosion. As long as the forest floor is not disturbed, soils are virtually erosion proof from the action of surface water.

Timber harvest activities, road building, and deterioration of roads and recreation trails are the most common contemporary sources of erosion in forests. Prescribed burns that create excessive ground temperatures and expose the root layer can also increase the potential for erosion. The potential for erosion from timber harvest is greatest on roads, landings, and skid trails while they are in use. Each of the Northern United States has voluntary Best Management Practices that have been developed as guides to minimize erosion and subsequent sedimentation owing to timber harvest activities. National forests have mandated standards and guides designed to prevent erosion and sedimentation from timber harvest, recreational activities, and prescribed burning.

Soil erosion from land clearing is a significant factor in the natural history of the region. Most of the land in the Northern United States was covered by forest before colonial expansion. In the 18th and 19th centuries, more than 13 square miles of land was cleared for farm and settlement uses per day. Intensive agriculture and pasturage in areas unsuited to those uses increased erosion. Many of today's forests occupy former agricultural lands that were abandoned, at least in part, because of erosion. Erosion accompanied the extensive timber harvests and slash fires that followed European settlement. In fact, many of the 12 million acres in the national forest system in the East allocated for watershed protection were founded on "the lands that nobody wanted" because of low productivity associated with soil erosion (Shands and Healy 1977) (figure 4.3). The extensiveness of this activity is difficult to fathom. For example, by 1895, nearly two-thirds of Pennsylvania's 27 million acres of forest had been cut. In 1900, 80 million acres of land lay barren in the East, and wildfires consumed an area the size of New York and New Jersey each year with devastating effects on watersheds and their soils. Historical erosion affected water quality as it became the source of sediment deposited in many streams and rivers across the Northern United States. In fact, the sedimentation problems created by actions taken a century or more ago still plague many streams in forested watersheds today.

Figure 4.3. Logging in New Hampshire's White Mountains in the early 1900s typifies the extensive harvesting that occurred across the Northern United States (USDA Forest Service photo).

Soil stabilization and erosion prevention were national priorities between 1930 and 1960, when gully restoration and tree planting were key activities of the

Civilian Conservation Corps and the Soil Bank Program. Today's USDA Natural Resources Conservation Service originated as the Soil Conservation Service with a key mission of soil conservation on agricultural lands.

Indicator 19. Area and percent of forest land managed primarily for protective functions (e.g., watersheds, flood protection, avalanche protection, riparian zones)

Forests can provide protection for watersheds and riparian areas. They can reduce flooding and help prevent avalanches. Comprehensive figures are not available on the amount of land in the Northern United States dedicated specifically for these purposes, but there is information on the types of ongoing management activity that provide protection of these values. In most cases, forests managed for timber, wildlife, recreation, or other values also protect critical areas. Generally forest harvesting and road building are excluded from avalanche-prone areas.

Watershed Protection

Forests help protect the characteristics of a healthy watershed. Watersheds with large amounts of undisturbed forest land generally have good water quality and relatively stable stream systems. In an undisturbed forest, the soil is shielded from rain by the tree canopy and covered by a protective layer of organic material. The porous surface layers of forest soils in the Northern United States generally maintain rates of infiltration in excess of rainfall intensities. As long as the forest floor is not disturbed, soils are virtually erosion proof from the action of surface water. This high infiltration capacity also results in moderation of high streamflow, which benefits stream stability and lowers the potential for sediment discharge into lakes, streams, and wetlands.

What makes a healthy watershed?

- Stable streambanks and channels
- Productive aquatic systems
- Woody debris and critical habitats
- Natural riparian corridors
- Produces quality water for desired uses
- Absorbs rain and moderates flooding
- Low rates of erosion and sedimentation
- Capacity for self-repair
- Supports public needs and uses

Clean water is a key resource protected by forested watersheds. Preliminary data assembled by the U.S. Environmental Protection Agency in response to the Safe Drinking Water Act Amendments of 1996 indicate that nearly 4,000 water systems draw their supply from surface waters in the Northern United States providing service to over 76 million people (table 4.1, appendix 4–A). Utilities and water districts often own land important as surface and groundwater source areas. In fact, many of the 12 million acres in the National Forest System in the Northern United States was allocated for watershed protection, as are many State forest and park lands, such as the "forever wild lands" of the Adirondack and Catskill Parks in New York. A critical emerging forestry specialty is the management of forests to maximize drinking water quality and supply. For example, the Northeastern Association of Watershed Forest Managers, founded in 1996, is a professional association dedicated to this very purpose.

Table 4.1. **Surface water supply sources**. Forested land in the Northern United States helps protect surface water supplies for over 76 million people[1] (USDC Bureau of the Census 2002, U.S. Environmental Protection Agency 1997a). See appendix 4–A for a breakdown by State.

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.

The Safe Drinking Water Act Amendments of 1996 require the development of source water assessments and protection strategies that may lead to targeting of forest land conservation as a preventative measure. Prevention of water quality degradation at the source is a more cost-effective strategy for ensuring water quality than is building water quality treatment plants to remove pollutants and impurities. The majority of watersheds in the Northern United States can benefit from the maintenance and conservation of forest land as part of a prevention strategy.

Seldom do public agencies or utilities have control over all lands affecting the quality of the water they rely upon. In fact, over three-quarters of the surface water supply systems in the Northern United States are affected by activities on private forest lands. Therefore, public and private forest landowners share the responsibility to protect drinking water. This is leading to some vital public-private partnerships. For example, the New York City Department of Environmental Protection must safeguard the drinking water supply to 9 million residents in the New York metropolitan area. The city is implementing an aggressive effort to purchase forest lands and conservation easements in key areas. It is also working with Federal and State forestry agencies and private industry to promote voluntary programs to protect water quality without compromising the economic viability of farming and forestry in the region. The cost of this protection strategy is far less than the estimated $7 billion needed to construct and operate filtration plants.

Various Federal, State, and privately funded efforts achieve land protection through fee simple and use restriction approaches in watersheds. Over 350 private land trusts have identified watershed and water quality protection as an objective of their efforts in the Northern United States (Land Trust Alliance 1998). The USDA Forest Service Forest Legacy

Program provides States with the ability to purchase properties or conservation easements where forest lands provide high watershed values and are threatened by conversion to other land uses. As of April 30, 2000, 111,290 acres had been placed under protective status in the Northern United States through the Forest Legacy Program. Federal and State funding can also be used as leverage to obtain private funding for conservation efforts. For example, in 1999, Federal, State, and private funds were used for the largest ever single purchase of forests in the State of Maryland, placing 67,000 acres of forest long managed by the Chesapeake Corporation under State control, primarily to protect the quality of the Nanticoke River.

Wetlands

Wetlands provide a multitude of ecological, social, and economic benefits. They provide habitat for fish, wildlife, and a variety of plants. They are nurseries for many saltwater and freshwater fish and shellfish of commercial and recreational importance. Wetlands are important landscape features because they hold and slowly release floodwater and snowmelt, recharge groundwater, act as filters to cleanse water of impurities, recycle nutrients, and provide recreation and wildlife viewing opportunities for millions of people (Welsch and others 1995). The Northern United States was estimated to have 41 million acres of wetlands on non-Federal land and water areas in 1997. Forested wetlands compose the largest segment, over 28 million acres (68 percent) (figure 4.4). These forested wetlands represent 43 percent of the total for the conterminous United States (USDA NRCS 2000) (appendix 4–B).

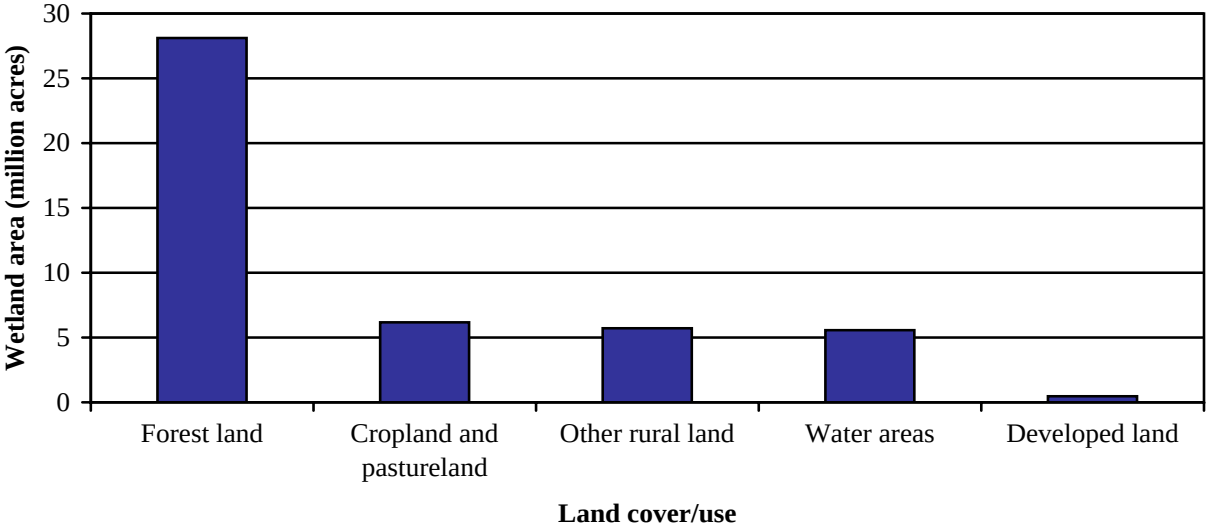


Figure 4.4. **Palustrine[1] and estuarine[2] wetlands on water areas and non-Federal land by land cover/use in the Northern United States, 1997**. Forested wetlands compose the largest percentage of wetlands in the Northern United States (USDA NRCS 2000).

[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 by 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).

Note: Cropland and pastureland includes Conservation Reserve Program land.

Efforts to retain and manage forested wetlands can preserve the water quality benefits they provide to people in the Northern United States. Gross losses of palustrine and estuarine wetlands in the Northern United States between 1992 and 1997 total 131,800 acres and represent 26 percent of national losses. Net loss was 68,000 acres. Losses were from actions that changed them to some form of upland land use such as agriculture (33 percent), silviculture (18 percent), development (46 percent), or other uses (3 percent).

Losses from the forested wetlands category often occur due to conversion to other wetland types without loss of wetland character. Many losses in the forested wetlands category are temporary, as wetlands revert to a forested condition following harvest. External threats include influences that lead to conversion of wetlands and actions that degrade the ecosystem. Forested wetlands face conversion to ponds, reservoirs, and agricultural use. Pollution, drainage, urban development, and other activities that may not necessarily occur in wetlands, affect wetlands and result in severe degradation and impairment of wetland functions.

According to estimates of the USDI Fish and Wildlife Service, circa the 1780s the Northern United States had roughly 80 million acres of wetlands, roughly twice as many as today (Dahl 1990) (appendix 4–C). Between 1986 and 1997 the national rate of wetland loss was 58,000 acres annually, an 80-percent reduction in the rate experienced from the mid-1970s to the mid-1980s. The loss of forested wetlands declined from 6.2 percent annually in the mid-1970s to mid-1980s (Dahl and Johnson 1991), to 2.3 percent annually in the mid-1980s to mid-1990s (Dahl 2000).

Riparian Areas

Riparian areas are landscape features that have many of the same general values and land use problems as wetlands.

Riparian areas are the lands adjacent to a body of water, stream, river, marsh, or shoreline. Riparian areas form the transition between the aquatic and the terrestrial environment. A riparian area may include several riparian ecosystems. Riparian ecosystems include the soil, surface structure (woody debris, rocks, depressions), and the plant and animal communities. Because of their position in the landscape, riparian areas interact with the flow of surface and groundwater from upland areas, and play an important role in filtering runoff, reducing excess nutrients and other pollutants, and providing critical ecological values such as shade, food, and structural habitat. Species abundance and richness tend to be greater in riparian ecosystems than in adjacent uplands (Odum 1979). Although healthy riparian vegetation of any kind is desirable, forests provide the greatest number of benefits and highest potential for reaching both water quality and living resource goals. As functional ecosystems, they have large energy, nutrient, and biotic interchanges with aquatic systems on one side and with upland terrestrial ecosystems on the other. Their linear nature and high edge-to-area ratios contribute to this functionality, which is why riparian areas are best evaluated and managed as parts of larger landscapes.

Streamside forests are important riparian areas. Under natural conditions these forests would protect most of the rivers and streams in our Nation, but deforestation associated with agricultural and urban expansion has drastically reduced their extent (figure 4.5). In agricultural areas, many floodplain forests have been reduced to isolated fragments no longer

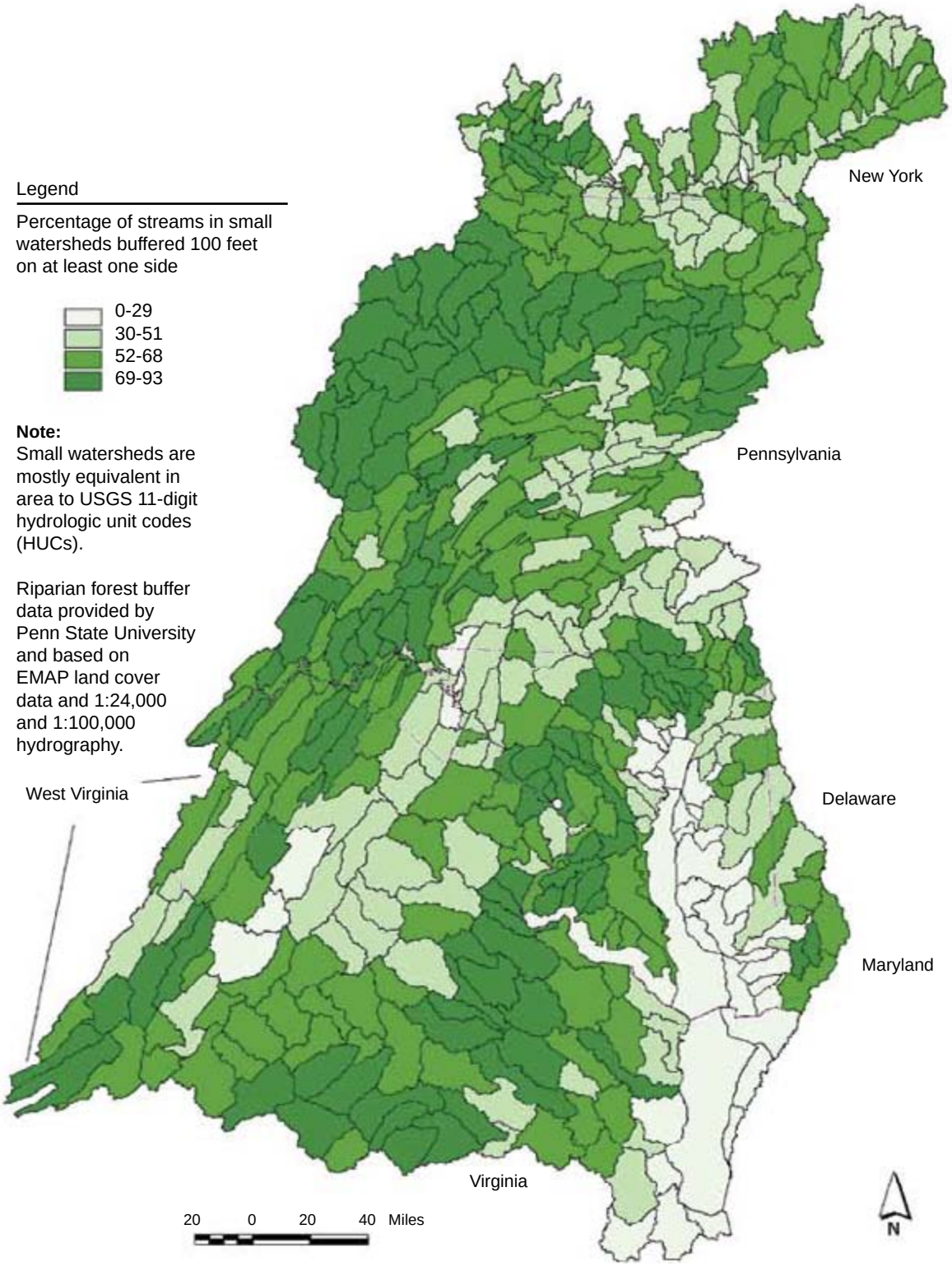


Figure 4.5. **Riparian forest buffers in the Chesapeake Bay watershed**. A study by the Forest Service and the U.S. Environmental Protection Agency Chesapeake Bay Program suggests that over 45,000 miles of streams in the Chesapeake Bay watershed are without adequate riparian forest cover (Day and others 1997).

capable of supplying the river with essential woody debris or an adequate organic food supply for healthy fisheries. 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).

In the Northern United States, the presence or absence of trees adjacent to stream channels may be the single most important factor altered by humans that affects the structure and function of the stream macro-invertebrate community on which many aquatic species depend. On a watershed basis, almost half of the watersheds in the Northern United States are likely to have more than 56 percent of their stream miles in forested cover (forest within approximately ⅓ mile of a stream), nearly a fifth of the watersheds have more than 89 percent of their stream miles forested; and less than a fifth have less than 22 percent of stream miles forested (Jones and others 1997). Restoring streamside forests may be a necessary prerequisite to restoring a disturbed stream system to a natural or quasi-natural state (Sweeney 1993); however, few natural riparian zones remain to serve as models (Naiman and others 1993).

Restoration of riparian forests can help remove or ameliorate the effects of pollutants in runoff, and increase the biological diversity and productivity of aquatic communities by improving habitat and adding to the organic food base. Riparian forests can also play a large role in buffering urban and agricultural development. Conserved and managed as buffers, riparian forests can dramatically reduce the impacts of land use activities (Welsch 1991). In fact, studies show dramatic reductions from 30 to 98 percent in nutrients, sediments, pesticides, and other pollutants in surface and groundwater after passing through a riparian forest buffer (Lowrance and others 1984). Ninety-five percent of the watersheds in the Northern United States show moderate to high levels of agricultural runoff (U.S. Environmental Protection Agency 1997b). Agricultural runoff is one type of nonpoint pollution that can be reduced by using streamside forests as buffers.

The Federal Wild and Scenic Rivers and the American Heritage Rivers Programs provide opportunities to protect streamside forests and riparian functions. There are 39 Wild and Scenic River segments covering 1,803 miles of river and 9 nationally designated American Heritage Rivers in the Northern United States (USDI National Park Service 2001) (see appendix 7–E).

Flood Protection

Trees in a floodplain influence the hydrology of the riparian ecosystem, especially during floods. Floodplain forests stabilize streambanks and reduce the destructive energy of streamflow. Species native to floodplains can thrive despite periodic flooding and associated sediment deposition. The floodplains of many perennial streams in the Northern United States were cleared for agricultural purposes or converted to agriculture after streams were channelized. In contrast to flooding in forested floodplains, flooding and sedimentation of agricultural land often smothers crops and reduces yields. Floodwater damage to farmland in stream floodplains can often be serious enough that the landowners will convert that land to forest land.

Since the arrival of European settlers, many wetlands have been drained, and streams and rivers straightened and channelized to increase their ability to carry floods or drain the land quickly. These changes disrupt the natural dynamics of water storage in a watershed. The downstream effects of channelization include high peak flows, high erosion forces, unstable streambanks and beds, heavy sediment loads, and reduced habitat for aquatic species. Channelization also changes the hydrology of the stream and flood pattern in streamside forests. The water in channelized streams is continually at work eroding banks and depositing sediments into order to reestablish a natural meander pattern and floodplain. The deleterious effects of historical channelization are evident in aquatic ecosystems and riparian areas to this day.

Avalanche Protection

A limited area in the Northern United States is prone to avalanche danger. Exclusion of active harvest and road building is a common means of ensuring safety in avalanche-prone areas.

Indicator 20. Percent of stream kilometers in forested catchments in which stream flow and timing has significantly deviated from the historic range of variation

Land cover and use ultimately affect the hydrology of streams and lakes in a watershed. Storm hydrographs for streams are used to track changes in streamflow and timing of peak and low flows (figure 4.6). The amount of streamflow and the timing of peak flows depend on local watershed characteristics and the amount and intensity of rainfall, coupled with antecedent soil-moisture conditions (Kochenderfer and others 1996).

In the Northern United States, the highest volume of runoff occurs annually in spring owing to snowmelt; however, flood peaks associated with major storms or localized thunderstorms can occur any time of year. The conversion of forest land to agriculture or urban development effects fairly permanent changes in runoff. The rate of delivery of water from land to a stream is increased, and thus flood peaks from all storms are higher than when the watershed was forested. Forest land tends to have a moderating influence on peak flows relative to agricultural and urban development.

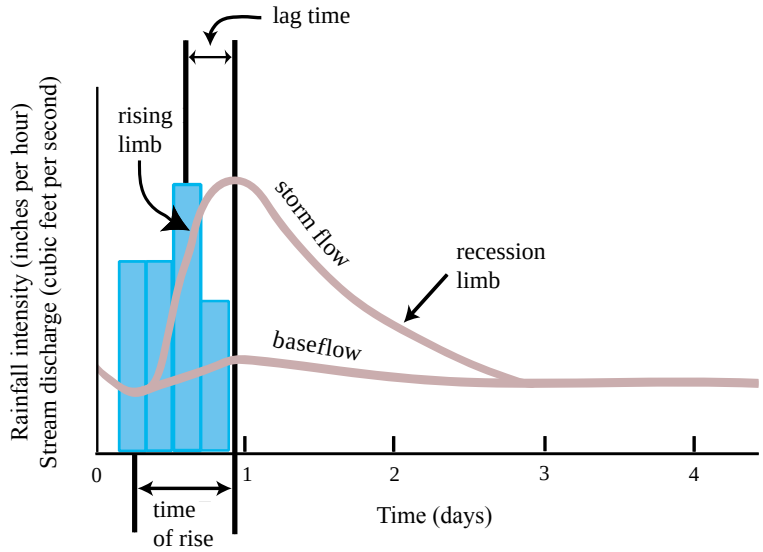


Figure 4.6. **Storm hydrograph**. A storm hydrograph is used to track the volume of water passing a point over time. Stream discharge on a hydrograph can be divided into stormflow and baseflow. Baseflow sustains river ecosystems between rains. Lag time is the difference in time between the peak rainfall intensity and peak stream discharge (Federal Interagency Stream Restoration Working Group 1998).

Land Cover

Forty-one percent of the Northern United States is in forest cover. Studies have shown detrimental changes in streamflow and timing as forest cover declines. For example, in an 11.5-million-acre area surrounding the Washington, DC-Baltimore, MD, corridor, forest lands declined from 51 to 37 percent between 1973 and 1997, resulting in a 19-percent increase in stormwater runoff (American Forests 1999). Although large blocks of contiguous forest still exist, most catchments are a mosaic of forest, farm, and developed land. Indeed forest loss to development is a factor in watershed health to varying degrees across the Northern United States (figure 4.7).

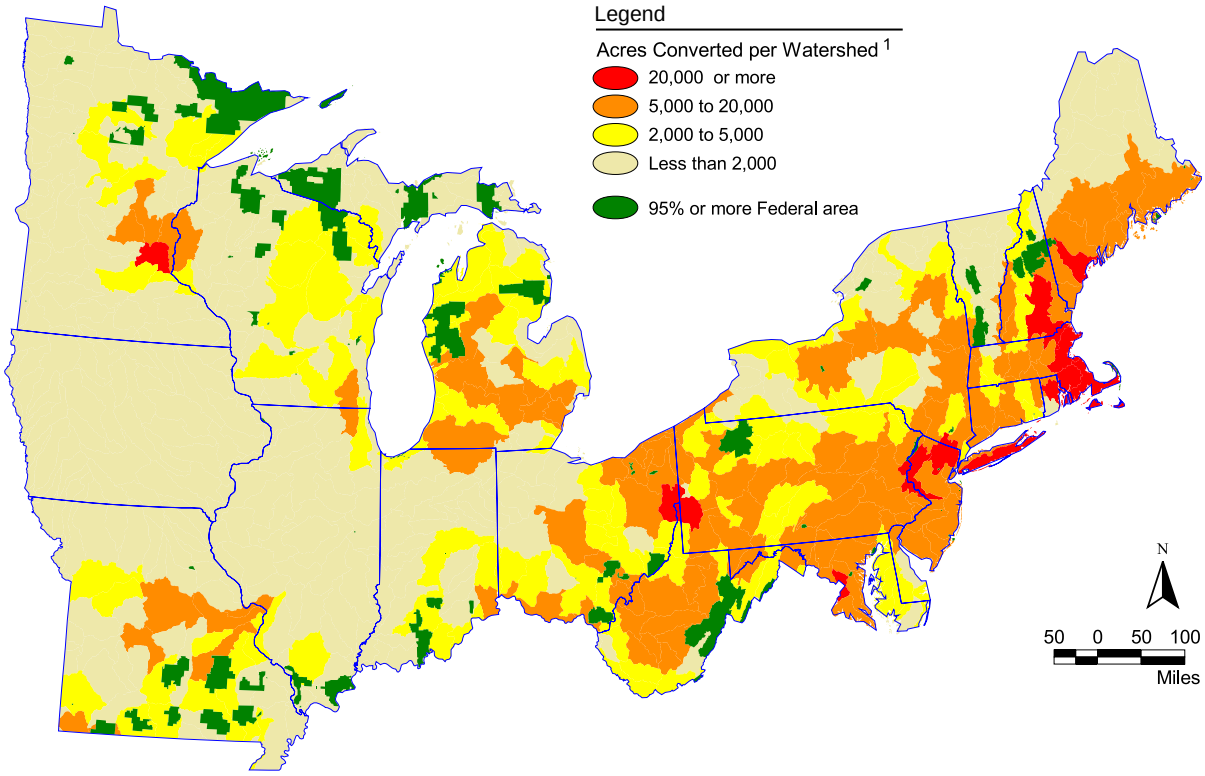


Figure 4.7. **Acres of forest land converted to developed land, by watershed, from 1992 to 1997** (USDA NRCS 2000).

[1]Watersheds are defined as U.S. Geological Survey Hydrologic Unit Codes (8-digit).

Nearly 35 percent of the Northern United States is classified by the Bureau of the Census as metropolitan area; 6 percent is further classified as urban area. The entire State of New Jersey is classified as metropolitan area; therefore, all of its tree cover occurs in metropolitan areas. Twenty-two percent of the New Jersey's tree cover is in urban areas. Among the remainder of the Northern United States, metropolitan areas contain between 10 and 89 percent of each State's tree cover; urban areas contain between 1 and 14 percent (Dwyer and others 2000) (appendix 4–D).

Metropolitan and urban areas of the Northern United States are more forested than the national average. Metropolitan areas of the Northern United States have tree cover that ranges from 36 percent in Missouri to around 65 percent in Maine and West Virginia compared with the national average of 25 percent. Tree cover within urban areas ranges from 9 percent in Rhode Island to 47 and 49 percent in Maine and New Hampshire, respectively, compared with the national average of 6 percent. Sprawl is causing rapid losses of forest cover in many parts of the Northern United States. The most heavily affected urban regions are associated with major cities such as Boston, Hartford, New York, Buffalo, Pittsburgh, Philadelphia, Baltimore, Washington, DC, Columbus, Cincinnati, and Chicago.

Impervious Surfaces

Changes in the stream hydrograph may be caused by increases in impervious surfaces in urban areas. **Impervious surfaces** include road surfaces, sidewalks, roofs, and compacted soils. Impervious surfaces in developed areas cause rainfall to run off into streams and other water bodies more rapidly than under natural conditions (figure 4.8). Streams may begin to show degradation of natural hydrology and biological integrity when 10 percent of the watershed is covered by impervious surfaces (figure 4.9). When impervious surfaces cover more than a quarter of the watershed, a stream may no longer support vibrant natural communities (Schueler 1995).

Timber Harvest

Timber harvesting can temporarily increase annual stream discharge until regrowth of the forest occurs. The quantity and character of harvest in a watershed are factors. Work at Hubbard Brook Experimental Forest in New Hampshire found that changes in runoff were not measurable unless more than 25 percent of the basal area of a forested area was removed (Hornbeck and others 1993). Increases in streamflow following harvest are most pronounced in the summer because of reduced evapotranspiration. This increase has no detrimental effects and in some cases may be beneficial to aquatic life.

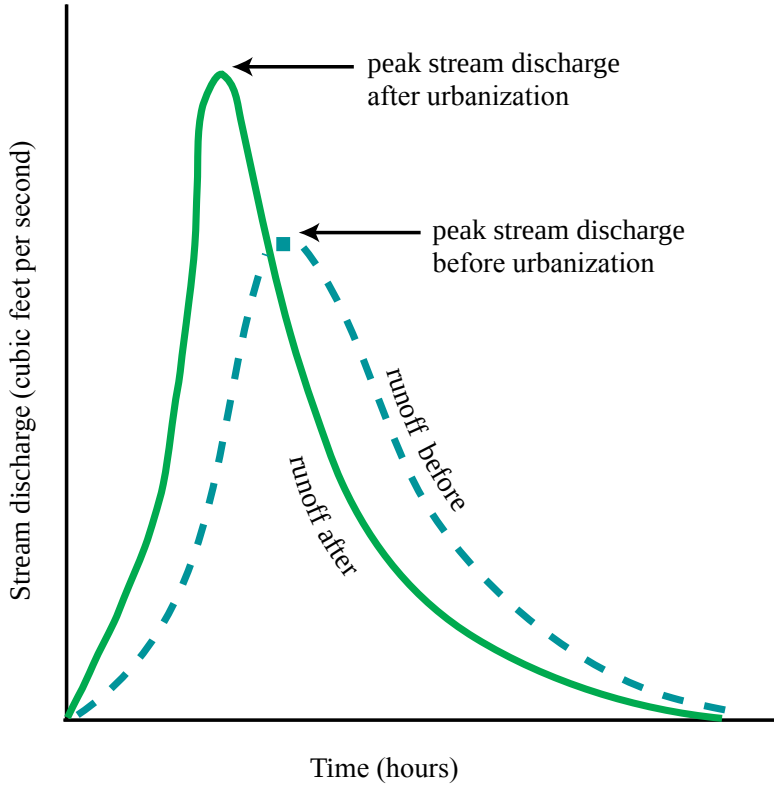


Figure 4.8. **Streamflow before and after urbanization**. Runoff enters a stream faster following urbanization, leading to higher peak stream discharge than in a natural system (Source: adapted from Federal Interagency Stream Restoration Working Group 1998).

As road densities increase and the extent of harvest increases in a watershed, resulting increases in water yield can raise the potential for erosion and sedimentation problems. Best management practices are designed to eliminate those effects.

Indicator 21. Area and percent of forest land with significantly diminished soil organic matter and/or changes in other soil chemical properties

Organic matter and the chemical balance in a soil are important to plant health and productivity (Hornbeck and Leak 1992). The interactions among nutrients, water, soil microbes, vegetation, and wildlife are dynamic and intricate. Issues that concern forest managers and affect soil organic matter content and nutrient stores include effects related to timber harvesting, land use history (e.g., fire, agriculture), acid deposition, and the effects of nutrient losses due to soil erosion (indicator 18).

Effects From Timber Harvesting

Timber harvesting removes soil nutrients, especially the base cations calcium (Ca), magnesium (Mg), and potassium (K), as part of the fiber taken from the site. Harvesting that increases the exposure of soil and residues to light, heat, and moisture results in accelerated decomposition of organic matter (and some small acceleration of chemical weathering of inorganic minerals in soils and rocks). This makes more nutrients available for transport. Nitrogen, which normally would have been taken up by living trees in the form of ammonium (NH_4^+), is converted by soil microbes to nitrate (NO_3^-), a form of nitrogen easily transported in water. This conversion results in a temporary flush of hydrogen atoms that replace base cations on soil particles and cause these nutrients to move into the soil solution where they are susceptible to leaching.

The intensity and frequency of harvesting affects soil nutrient losses. In the short term, a one-time selection or thinning harvest will have less impact than a clearcut, and a conventional bole-only clearcut harvest has less impact than a whole-tree clearcut harvest. Hardwood thinning at age 60 and clearcut at age 120 may have less impact than frequently applied selection harvest. Precautions such as harvesting after leaf fall and using less intense methods on low-fertility sandy, glacial outwash have been recommended to conserve soil nutrients.

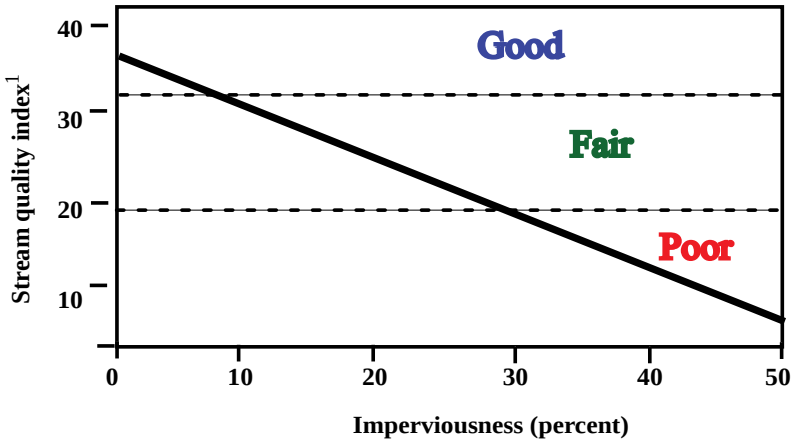


Figure 4.9. **Effects of imperviousness on stream quality index**. Streams show signs of degradation of natural hydrology and biotic integrity when watershed imperviousness reaches 10 percent (Schueler and Galli 1992).

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

Effects From Acid Deposition

Acid deposition includes acid precipitation and dry deposition (acidic particles). Acidity is measured by using a logarithmic pH scale. That is, a substance with a pH of 6 is 10 times more acidic than one with a pH of 7. Generally any precipitation that has a pH value of less than 5.6 is considered to be acid precipitation because pH 5.6 is the pH value of water in equilibrium with carbon dioxide concentrations in air. Soil acidity, which affects the balance of nutrients available to plants and animals in the soil, is affected by acid deposition.

Acid deposition can trigger changes in soil chemistry, including lowered soil pH and the leaching of nutrients from the site. Decreases in pH allow aluminum to move from exchange sites into the soil solution, potentially disrupting the uptake of base cations by vegetation. For example, studies in New England indicate that soluble aluminum may induce a calcium deficiency in red spruce (*Picea rubens*) (Shortle and Smith 1988).

Cumulative Effects

A key question is how the cumulative effects of soil erosion, harvest, and acid deposition will affect future forest health and productivity. Widespread reductions of productivity owing to changes in soil conditions are not clearly demonstrated by empirical evidence to date. For example, in New England, stands of red oak (*Quercus rubra*) (a calcium-demanding species) growing in areas with potential to be affected by soil acidification, even in previously cleared and farmed sandy soils, are growing at rates comparable to the regional average for those site conditions (Hallett and Hornbeck 1997). And long-term studies show biomass accumulation in northern hardwood and northern hardwood-spruce forest types is not measurably different before or after 1950 when acid deposition may have begun in earnest (Nuengsigkapian 1998). Sugar maple (*Acer saccharum*) is showing some health decline in parts of the Northeast, but there are other stress factors in addition to nutrient loss and soluble aluminum affecting the species (Horsley and others 2000).

The current thought is that the degree of impact in the long term is expected to vary depending on site conditions. Site conditions may include land use history, landscape position, soil parent material mineralogy, surface soil depth, and soil drainage and texture. Productivity and health on some forested sites are expected to remain unaffected by the nutrient losses mentioned above because of large nutrient stores in the soil. Other sites will be more susceptible to nutrient losses owing to inherently low nutrient stores; to nutrient depletion by past activities such as farming, fire, and intensive harvesting; or both (Shortle and Bondietti 1992).

Indicator 22. Area and percent of forest land with significant compaction or change in soil physical properties resulting from human activities

Soil Compaction

Soil compaction is measured by an increase in soil bulk density. **Bulk density** is the mass of soil per unit of volume. Soil with high percentages of clay naturally have higher bulk densities than sandy soils. Bulk densities associated with loam soils are usually ideal for plant establishment and growth. Soil compaction can result from the use of heavy equipment in timber harvest activities or from human and vehicle use associated with forest

recreation. Compacting soils affects their ability to store moisture or allow water movement, which affects nutrient uptake. Vegetation growth and regeneration can be affected by soil compaction.

The USDA Forest Service is implementing a series of long-term productivity studies to test the single and combined effects of total tree harvest, varying degrees of compaction, and organic matter removal in ecosystems with a range of tree and site characteristics. The USDA Forest Service North Central Research Station has three Long-Term Productivity study sites in the Northern United States. Five-year results from these sites, located on the Ottawa and the Huron-Manistee National Forests in Michigan, and Department of Environmental Conservation land in Missouri, indicate that all levels of compaction are not necessarily detrimental. Two early findings indicate that if organic matter is not removed, coarse soils may benefit from some degree of compaction with improvements in water-holding capacity and site productivity. Additional findings indicate that expected decreases in compaction owing to freeze-thaw cycles have not occurred within the 5-year period of study (Stone and Elioff 1997, Tiarks and others 1997).

Indicator 23. 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

Biodiversity is the extraordinary variety of life on Earth—from genes and species to ecosystems and the valuable functions they perform (Alonso and others 2001). Aquatic biological diversity is an important indicator of a healthy aquatic ecosystem. Waters of the Northern United States from the Upper Mississippi River Basin, east through the Great Lakes Basin to New England are home to a variety of fish and aquatic life, including unique native fish species such as brook char (*Salvelinus fontinalis*), lake char (*Salvelinus namaycush*), lake sturgeon (*Acipenser fulvescens*), Atlantic sturgeon (*Acipenser oxyrhynchus*), pallid sturgeon (*Scaphirhynchus albus*), Atlantic salmon (*Salmo salar*), and paddlefish (*Polydon spathula*). In addition, a substantial native sport fishery exists for walleye (*Stizostedion vitreum*), muskellunge (*Esox masquinongy*), yellow perch (*Perca flavescens*), largemouth bass (*Micropterus dolomieui*), smallmouth bass (*Micropterus dolumieu*), channel catfish (*Ictalurus pucntatus*), and northern pike (*Esox lucius*). Several nonindigenous Pacific salmon such as coho (*Oncorhynchus kisutch*) and chinook (*Oncorhynchus tshawytscha*) significantly contribute to the sport fishery in the Great Lakes Basin. The national forests, State fish and game agencies, and the U.S. Fish and Wildlife Service actively monitor and manage fish populations and habitats, but a comprehensive inventory and monitoring of biological diversity of all waters is lacking. However, ecological indicators for aquatic systems have been proposed (National Academy of Sciences 2000).

Biological diversity is affected by physical conditions, carbon and nutrient cycles, water temperature, and the fragmentation of lakes and streams as well as from nonnative aquatic invasives. Forests adjacent to lakes and streams can directly and indirectly affect many of these factors (figure 4.10).

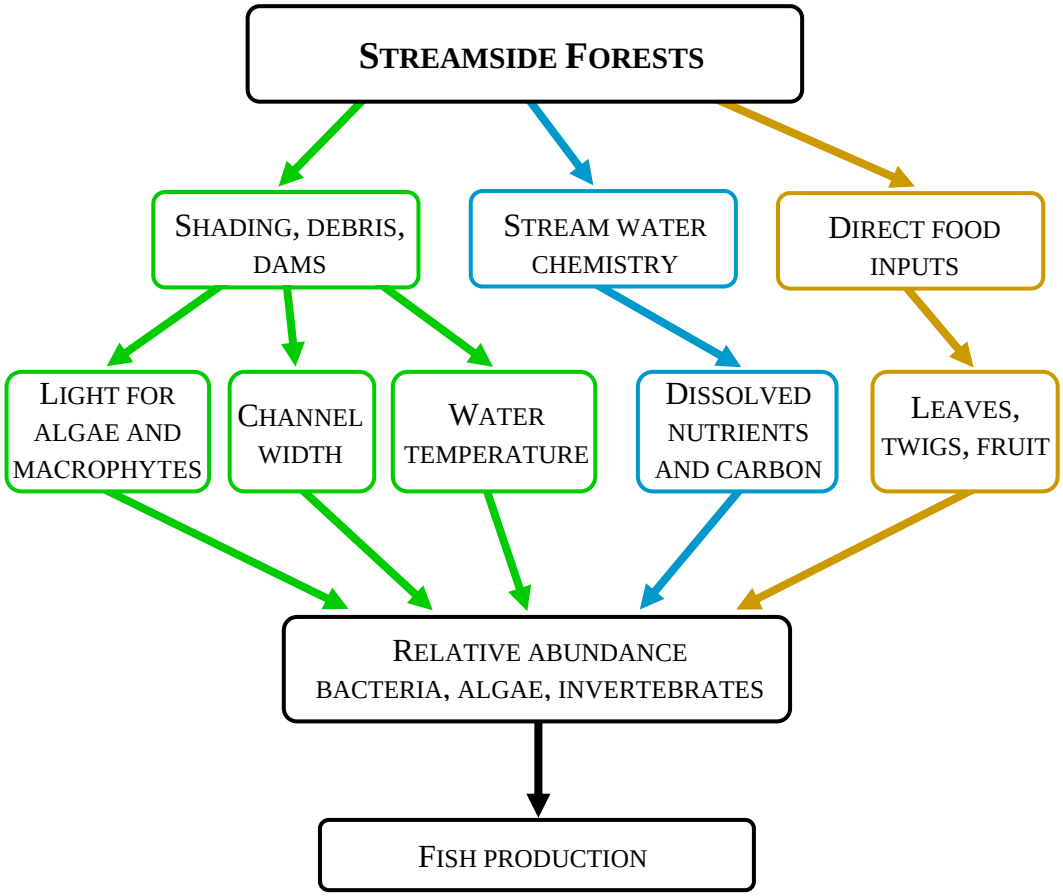


Figure 4.10. **Streamside forest functions**. Streamside forests affect factors such as water temperature, physical conditions, nutrient cycling, and food sources, which can alter the relative abundance of organisms in a stream ecosystem (Sweeney 1993).

Impacts to Aquatic Biological Diversity

In the Northern United States, the reduced biological integrity of many streams and lakes is partially the result of historical disturbances to watersheds and channels. The extensive clearing of forests in the 18th and 19th centuries followed by the alteration of streams through ditching and channelization in the 20th century dramatically changed the character of many watersheds and water bodies. Large quantities of sediment stored in the stream channels, lakes, and floodplains in many forested watersheds have their origin in land use practices of centuries past. The loss of riparian trees in the Northern United States has resulted in increases in temperature and decreases in instream woody debris critical to the successful maintenance of coldwater fish such as trout. In many areas, these losses of biological diversity are irreversible.

Modern factors affecting aquatic biological diversity include pollution, introduction of exotic and invasive species, changes in stream temperature, bank erosion, loss of woody debris or natural carbon, nutrient inputs from streamside vegetation, and sedimentation (table 4.2). For instance, sediment absorbs heat, which increases water temperature and leads to increased metabolism to which trout and sculpin (*Cottus* sp.) are particularly sensitive. Muddy water

Table 4.2. **The water quality "avalanche."** Each column indicates a sequence of potential impacts and effects to water quality and aquatic organisms[1] from the addition of sediment to streams (adapted from White 1998).

Physical Changes in Streams Affected by Sediment				
Absorbs heat Increases temperature	Muddies the water Decreases water clarity Increases siltation on bottom	Carries organic debris Decreases oxygen	Carries phosphorus Increases nutrients	Leaches heavy metals Increases toxicity
Direct and Indirect Effects on Organisms				
Raises metabolic rate, "wasted energy" not available for growth and reproduction Favors disease organisms	Reduces visual feeding Reduces visual mating Clogs gills during breathing Clogs gills during feeding Smothers nests and eggs Fills crevices in bottom gravel	Reduces pH (increases acidity) Phosphorus more available Ammonia more toxic Heavy metals leach more	Increases algal growth Higher daytime oxygen Lower night time oxygen Changes insect species from "shredders" to "grazers"	Causes developmental deformities Changes behavior Feeding Mate attraction and activity Parental care
Some Susceptible Species				
Temperature sensitive: Trout, sculpin	*Specialized insect feeders:* Darters, sculpin, many shiners, redhorse suckers, some chubs, madtoms, bluegill, longear sunfish *Clean gravel spawners:* Paddlefish, sturgeon, blue suckers, redhorse suckers, some chubs, some dace, some minnows, some shiners, burbot *Filter feeders:* Mussels, clams, some caddisflies *Delicate external gills:* Many mayfly larvae, stonefly larvae, dobsonfly larvae	*Oxygen sensitive:* Rainbow trout, bass, bluegill *Tolerant of low oxygen:* Carp, goldfish, green sunfish *Sensitive to acidity:* Frogs, salamanders, fish eggs; mats of fungi replace decomposing bacteria *Sensitive to pollution:* Brook lamprey, madtoms, blue sucker, greater redhorse, many darters, some shiners, a few minnows, dace, chubs	*"Shredder" insects disappear:* Sow bugs, some caddisflies, some stoneflies, craneflies *"Grazer" insects increase:* Snails, some caddisflies, flatheaded mayflies	*Sensitive developmental stages:* Eggs and young of most species, reproducing females *Complex parental care:* Bowfin, mudminnow, catfish, madtoms, some minnows, most bass, crappie, sunfish, sculpin, darters, stickleback

[1]Common and scientific names of species: bass (*Micropterus* sp.), bluegill (*Lepomis macrochirus*), blue sucker (*Cycleptus elongatus*), bowfin (*Amia calva*), brook lamprey (*Lampetra aepyptera*), burbot (*Lota lota*), caddisflies (order Trichoptera), carp (*Cyprinus carpio*), chubs (family Cyprinidae), clams (class bivalva), craneflies (family Tipulidae), crappie (family Centrarchidae), dace (*Rhinichthys atratulus*), darters (*Etheostoma* sp.), dobsonfly (*Corydalus cornutus*), flatheaded mayfly (family Heptageniidae), frogs (*Rana* sp.), greater redhorse (*Moxostoma valenciennesi*), green sunfish (*Lepomis cyanellus*), goldfish (family Cyprinidae), longear sunfish (*Lepomis megalotis*), madtoms (*Noturus* sp.), mayfly (order Ephemeroptera), minnows (family Cyprinidae), mudminnow (*Umbra limi*), mussels (order unionoida), paddlefish (*Polydon spathula*), rainbow trout (*Oncorhynchus mykiss*), redhorse suckers (*Maxostoma* sp.), salamanders (order Caudata), sculpin (*Cottus* sp.), shiners (*Notropis* sp.), sturgeon (*Acipenser fulvescens*), stonefly (*Plecoptera*), suckers (*Catostomus* sp.), sunfish (*Lepomis* sp.), stickleback (family Gasterosteidae).

reduces visual feeding of specialized insect feeders (e.g., darters [*Etheostoma* sp.], sculpin, and many shiners [*Notropis* sp.]). Resilient fish populations and the diversity and abundance of macroinvertebrates are indicators of healthy lake and river systems.

Salmon runs throughout the Northern United States have declined drastically over the years owing mainly to the installation of hydropower dams and other blockages to fish migration. Salmon restoration programs with both habitat and stocking components are active in the Great Lakes and Atlantic fisheries. Public conservation and sport fishing organizations like Trout Unlimited are important partners with Federal and State agencies in protecting, and in some cases restoring, the productive potential of aquatic ecosystems.

There are certain harmful exotic species affecting aquatic resources and their use. Plants include European frog-bit (*Hydrocharis morsus-ranae*), hydrilla (*Hydrilla verticillata*), *Phragmites* sp., flowering rush (*Butomus umbellatus*), purple loosestrife (*Lythrum salicaria*), and water chestnut (*Trapa natans*). Eurasian watermilfoil (*Myriophyllum spicatum*) reduces invertebrates and fish such as bluegill (*Lepomis macrochirus*) and largemouth bass. About 58 percent of native fish species listed as threatened or endangered are documented as threatened by exotics (Dudley 1994). Native trout, walleye, and catfish are susceptible species. Exotic fish species include popular species such as bass, brown trout (*Salmo trutta*), and rainbow trout (*Oncorhynchus mykiss*), as well as carp (*Cyprinus carpio*), round goby (*Neogobius melanostomus*), rudd (*Scardinius erythrophthalmus*), Eurasian ruffe (*Gymnocephalus cernuus*), white perch (*Morone americana*), and sea lamprey (*Petromyzon marinus*). Hybridization of introduced fish species with native species has reduced genetic diversity. Exotic crustaceans include the rusty crayfish (*Orconectes rusticus*) and the zebra mussel (*Dreissena polymorpha*). Mute swans (*Cygnus olor*) destroy wetland habitat and displace native wetland bird species. Nutria (*Myocastor coypus*) are a concern in coastal marshes.

Aquatic Species Status

The Natural Heritage Network and The Nature Conservancy have assessed the status of plants and animals in most States and documented the species with the greatest danger of being imperiled by impaired waters. Of 642 watersheds across the Northern United States, a quarter of them had five or more known species at risk; a fifth had at least one species at risk; 47 percent had between two and five species at risk; and the status of 10 percent of the watersheds is currently unknown (U.S. Environmental Protection Agency 1997b). Threatened and endangered species were not necessarily indictors of poor water quality because they would more likely be present in watersheds with little or no impairment.

Nationally, 35 percent of freshwater fish, 38 percent of amphibians, and 56 percent of mussel species are considered imperiled by The Nature Conservancy (The Nature Conservancy 1997).

Forests and Aquatic Biodiversity

Sustainable forest management can contribute to healthy aquatic ecosystems. Actions taken to enhance fisheries include the following:

- Managing riparian vegetation to restore old growth and ensure a continual source of large woody debris adjacent to lakes and streams.

- Restoring streamside forest diversity and health.
- Managing riparian vegetation to discourage beaver habitation along important coldwater streams.
- Managing roads to minimize sedimentation.
- Reducing existing sediment input through stabilization and sediment traps.
- Managing recreation pressure on the aquatic system.
- Conducting habitat restoration activities.

State and private forest lands bear the greatest burden for conservation of biological diversity, although national forests and other public lands are important for protection of aquatic biological diversity at the regional scale.

Indicator 24. 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

There is a great deal of variability in the physical, chemical, and biological properties natural to water bodies of the Northern United States. For example, the area naturally has streams that support both warmwater and coldwater fisheries, and oligotrophic (nutrient-poor), mesotrophic (medium-nutrient), and eutrophic (nutrient-rich) lakes and ponds.

Current water quality monitoring is structured around efforts to determine the ability of water to meet criteria for designated uses rather than to measure the deviation from natural conditions. The U.S. Environmental Protection Agency (EPA) is moving toward a system of reference sites by ecoregion that in the future may provide baseline information for gauging the degree of variation from more or less natural conditions. Nearly all water bodies have been affected by human activity. Impacts to water chemistry, temperature, and sediment load are the result of development; industrial, agricultural, and urban pollution; and activities like dam building, channelization, forestry, and historical land clearing, among others. Even remote bodies of water have been affected through atmospheric deposition.

Water Pollution

Water pollution is the contamination of water with harmful substances. It is categorized as point or nonpoint source. **Point source pollution** comes from specific sources, such as sewage treatment plants or industrial facilities. The 1948 Federal Water Pollution Control Act (the "Clean Water Act") and its amendments through 1987 have done much to reduce point source contaminants. The progress in reducing concentrated pollution from specific sites has allowed the Nation to focus more resources on nonpoint source pollutants.

Nonpoint source pollution occurs when water, washing over the land, whether from rain, car washing, or the watering of crops or lawns, picks up an array of contaminants and finds its way into our waterways. Nonpoint source pollutants include sediment, nutrients, pesticides, animal wastes, road salt, and other substances that enter the water supply as components of runoff and groundwater flow. The 1994 National Water Quality Inventory Report to Congress

states that nonpoint source pollution is the leading cause of impairment in the Nation's rivers and streams (U.S. Environmental Protection Agency 1995). Urban runoff in particular is the leading source of pollution in estuaries, the third leading source in lakes, and the fourth in rivers. Some areas in the Mid-Atlantic and Central States deal with seepage from coal and other metal mining operations.

Sedimentation associated with forestry is considered a nonpoint source pollutant. Eroded soil that reaches a stream is called **sediment**. Sedimentation can have detrimental effects on aquatic ecosystems, recreational opportunities, potable water supplies, and the lifespan of river infrastructure such as dams. Forestry accounts for a relatively minor amount of the total sediment load delivered to streams nationwide. A report by the Council on Environmental Quality indicated that in 1980, forest land accounted for only 5 percent of nonpoint source contributions of total suspended sediment nationwide (figure 4.11).

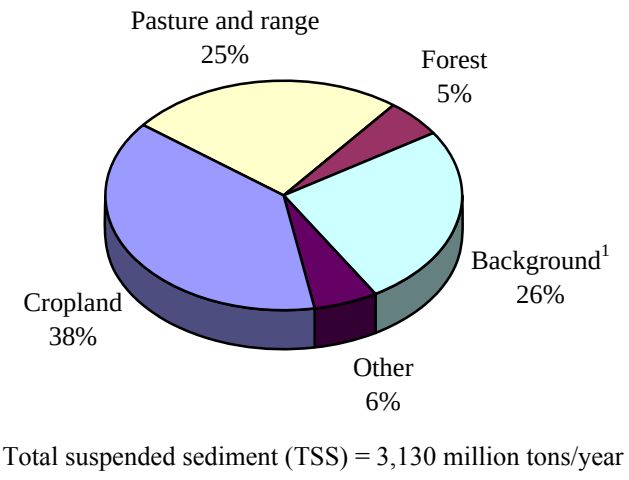


Figure 4.11. **Sources of suspended sediment**. Nationally, forest land contributed about 5 percent of the total suspended sediment from nonpoint sources in 1980 (Welsch 1991).

[1]Naturally occurring sediment in undisturbed landscapes.

EPA Index of Watershed Indicators

The EPA Office of Water recently developed an Index of Watershed Indicators to help organize and evaluate multiple sources of environmental information related to water resource quality. The EPA has compiled information on water resource quality conditions and watershed vulnerability to degradation on a watershed basis for 2,111 watersheds in the continental United States (U.S. Environmental Protection Agency 1997b, 1998a). Not every data theme was available for each of the Northern United States, and the quality and amount of information differed by State; therefore, the EPA ratings will change as more information is gathered. Information on water resource quality conditions includes rivers meeting designated uses, fish and wildlife consumption advisories, source water quality in relation to drinking water standards, contaminated sediment, pollutants, and wetland losses. Information on vulnerability to degradation includes species at risk, pollutants discharged above permitted levels, urban and agricultural runoff potentials, population change, hydrologic modifications caused by dams, and estuarine pollution susceptibility.

Of the 642 watersheds within the Northern United States as of June 1997, the assessment concluded 20 percent have "serious" water quality problems, 45 percent have "less serious" problems, and 16 percent have "better" water quality. Roughly 11 percent of the watersheds are highly vulnerable to future degradation. Water resources in areas with a predominance of

forest land are generally classified as having a "low vulnerability" for degradation and have either "better" water quality or "less serious" water quality problems. Water resources with "serious" water quality problems tend to be located in areas with high populations. Areas with "high vulnerability" to degradation are located along the Atlantic Coast where estuaries are threatened by pollution as well as in areas with high or growing populations (U.S. Environmental Protection Agency 1997b).

Unified Watershed Assessment

Section 319 of the Clean Water Act establishes a framework to manage nonpoint pollution sources. The most substantive recent effort under Section 319 is the development of unified watershed assessments. The aim was to provide a foundation for more integrated assessment and interagency cooperation on restoration of water quality and the health of aquatic systems. This "Unified Watershed Assessment" reported four categories of watershed condition (8-digit or 4th-field hydrologic unit code or HUC) with Category I the highest priority for Federal investment. These categories are used by States to develop strategies for watershed restoration and protection. Of 642 watersheds in the Northern United States, 80 percent are Category I compared with 68 percent nationwide (figure 4.12). The Forest Service has identified healthy watersheds as its own strategic priority and is redirecting funds to assist in the assessment and implementation of the action strategies in priority watersheds.

Unified Watershed Assessment Categories

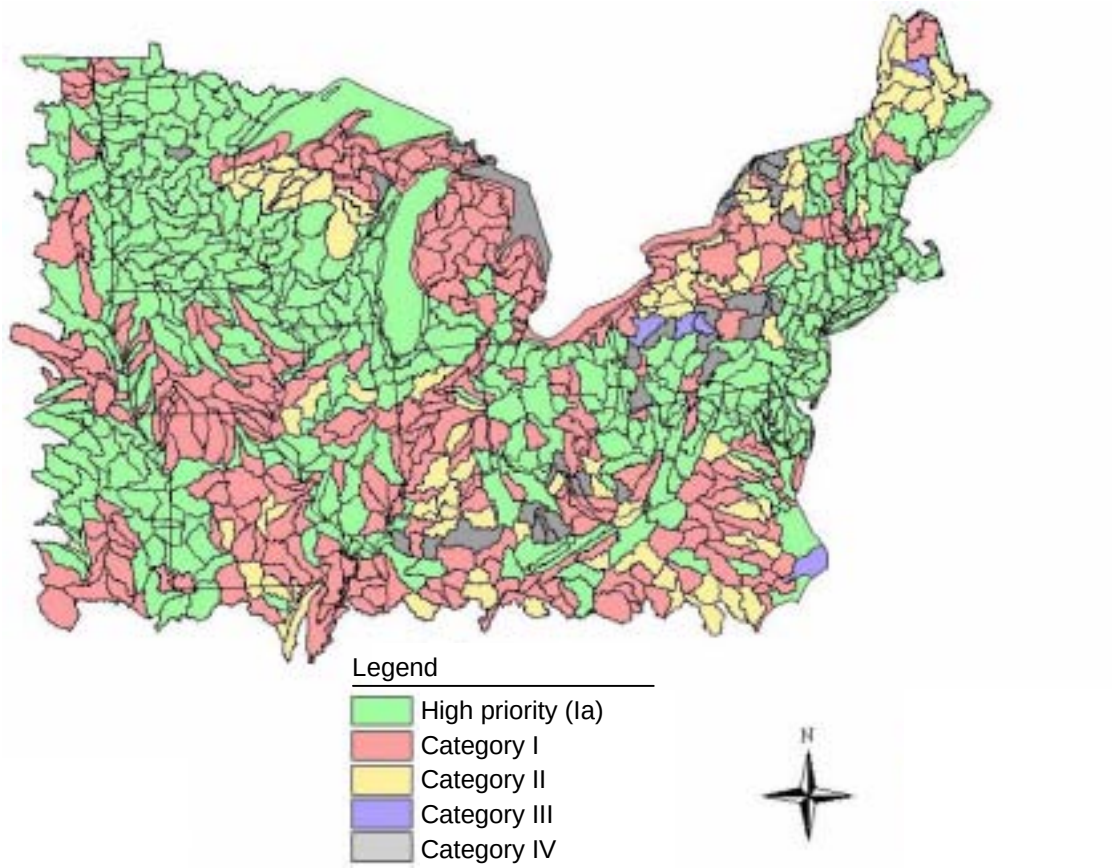
Category I: Watersheds in Need of Restoration. These watersheds do not meet, or face imminent threat of not meeting, clean water and other natural resource goals.

(Category Ia. first priority for implementation)

Category II: Watersheds Meeting Goals, but Needing Preventive Actions to Sustain Water Quality. These watersheds currently meet clean water and other natural resource goals and support healthy aquatic systems. These watersheds need continuing implementation of clean water and natural resource programs to maintain water quality and conserve natural resources.

Category III: Watersheds With Pristine or Sensitive Aquatic System Conditions on Lands Administered by Federal, State, or Tribal Governments. States and tribes work cooperatively with Federal land managers to identify watersheds with exceptional water quality, drinking water sources, or other sensitive aquatic system conditions, which are located on lands administered by Federal, State, or tribal governments, or other public entities.

Category IV: Watersheds With Insufficient Data to Make an Assessment. These watersheds lack data, critical data elements, or the data density needed to make a reasonable assessment.



Unified Watershed Assessment Categories	
Category I	Watersheds in need of restoration
Category II	Watersheds meeting goals, but needing preventative actions to sustain water quality
Category III	Watersheds with pristine or sensitive aquatic system conditions on lands administered by Federal, State, and tribal governments
Category IV	Watersheds with insufficient data to make an assessment

	Nationwide		Northern U.S.	
	Number	Percentage	Number	Percentage
Total 8-digit watersheds	2,260	—	642	—
Category I	1,545	68.4%	513	80.0%
Category Ia[1]	800	35.4%	256	40.0%
Category II	278	12.3%	90	14.0%
Category III	23	1.0%	6	1.0%
Category IV	414	18.4%	33	5.0%

[1]Category Ia—First priority for implementation (FY 1999–2000)

Figure 4.12. **Unified Watershed Assessment categories**. Of 642 watersheds in the Northern United States, 80 percent are Category I, compared with 68 percent nationwide (Source: USDA Forest Service). (Note: Category Ia is a subset of Category I.)

Indicator 25. Area and percent of forest land experiencing an accumulation of persistent toxic substances

Persistent toxic substances include industrial waste and toxic metals such as arsenic, cadmium, copper, lead, mercury, and zinc from mining operations. The effect on forest sustainability in the Northern United States is unknown; however, most occurrences would have effects locally rather than regionally.

Summary and Conclusions

High-quality soil and water are necessary for healthy, productive, sustainable forests. Conversely, forests contribute to the maintenance and productivity of the soil and water resources. Forests help trap sediment, transform nutrients, reduce pollution, moderate soil and water temperatures, stabilize soil, reduce flooding, and provide food for organisms that form the base of both the terrestrial and aquatic food chains.

The historical decrease in watershed forest cover throughout the Northern United States has implications for water quality. Decreased forest cover, and losses of floodplain forests and wetlands, along with increases in urban and suburban development, have permanently altered the hydrology of many streams, especially streams in urban areas and higher order streams throughout the region. Losses of riparian forests are greatest in agricultural and urban areas where the ability to buffer water bodies from the effects of nonpoint source pollution is most critical. Headwater streams are the most likely to have retained forest cover.

The Northern United States has abundant surface and subsurface water resources. Nearly all water bodies in the Northern United States have been affected by human activity. Impacts to water chemistry, temperature, and sediment load are the result of development; industrial, agricultural, and urban pollution; dam building; channelization; forestry; historical land clearing; and other activities. Even remote bodies of water have been affected through atmospheric deposition.

Many lakes, streams, wetlands, and estuaries in the Northern United States have reduced biological integrity. Nearly all inventoried watersheds have some aquatic species at risk. This is the result of historical disturbances to watersheds and channels, and modern factors such as pollution, the introduction of exotic and invasive species, changes in nutrient and carbon inputs from streamside vegetation, temperature changes, losses of woody debris, bank erosion, and sedimentation. Exotics are a factor for most native fish species listed as threatened or endangered. Hydropower dams and other blockages to migration have affected salmon.

The effects of settlement-era land clearing, slash fires, farming, and forest cutting are still visible in the lands and waters of the Northern United States. Current land use, forest management, and acid deposition are factors affecting soil nutrients, organic matter, energy cycles, and biota today but have not resulted in widespread changes in forest productivity to date. Instead, effects differ from site to site, for example, acid deposition effects on high-elevation red spruce. Timber-harvest activities, road building, and deterioration of roads and recreation trails are the most common contemporary sources of compaction and erosion on forested land. In contrast to historical land use practices, these activities usually result in localized impacts with little sedimentation of water bodies.

Appendix 4–A. Surface water systems by State with population served

State	Number of surface water supply systems	Population served
Connecticut	59	2,294,644
Delaware	5	438,025
Illinois	542	8,329,857
Indiana	107	2,264,424
Iowa	125	798,233
Maine	73	410,366
Maryland	56	3,780,694
Massachusetts	167	6,965,508
Michigan	281	5,349,765
Minnesota	37	1,405,387
Missouri	240	3,138,561
New Hampshire	50	491,634
New Jersey	93	5,219,045
New York	390	11,102,927
Ohio	292	6,334,755
Pennsylvania	431	8,909,158
Rhode Island	22	849,907
Vermont	78	323,302
Virginia	265	4,672,708
West Virginia	318	1,174,628
Wisconsin	42	1,630,370
Total	**3,999**	**76,496,707**

Source: USDC Bureau of the Census 2002, U.S. Environmental Protection Agency 1997a.

Appendix 4–B. Wetlands and deepwater habitats on water areas and non-Federal land by State, 1997

State	Palustrine and estuarine wetlands			Other aquatic habitats			Total
	Palustrine	Estuarine	Subtotal	Lacustrine	Other[1]	Subtotal	
	Thousand acres						
Connecticut	365.0	22.4	387.4	64.5	43.9	108.4	495.8
Delaware	164.8	98.0	262.8	24.4	261.1	285.5	548.3
Illinois	1,172.3	0	1,172.3	383.6	255.9	639.5	1,811.8
Indiana	700.5	0	700.5	166.6	146.4	313.0	1,013.5
Iowa	912.6	0	912.6	197.0	229.6	426.6	1,339.2
Maine	5,629.7	1.9	5,631.6	878.7	368.4	1,247.1	6,878.7
Maryland	729.3	228.6	957.9	45.4	1,579.8	1,625.2	2,583.1
Massachusetts	535.4	35.0	570.4	134.6	220.3	354.9	925.3
Michigan	6,021.4	0	6,021.4	803.9	243.7	1,047.6	7,069.0
Minnesota	10,863.8	0	10,863.8	2,359.5	694.5	3,054.0	13,917.8
Missouri	897.2	0	897.2	414.1	225.6	639.7	1,536.9
New Hampshire	488.1	6.5	494.6	160.9	61.1	222.0	716.6
New Jersey	531.3	209.3	740.6	86.7	430.9	517.6	1,258.2
New York	3,532.4	1.6	3,534.0	665.0	555.0	1,220.0	4,754.0
Ohio	898.4	0	898.4	186.0	169.2	355.2	1,253.6
Pennsylvania	918.4	0	918.4	247.5	200.6	448.1	1,366.5
Rhode Island	89.6	6.3	95.9	21.0	128.2	149.2	245.1
Vermont	571.1	0	571.1	226.8	34.2	261.0	832.1
West Virginia	98.1	0	98.1	78.0	88.6	166.6	264.7
Wisconsin	5,565.9	0	5,565.9	901.1	306.4	1,207.5	6,773.4
Northern U.S.	40,685.3	609.6	41,294.9	8,045.3	6,243.4	14,288.7	55,583.6
All U.S. (less Alaska)	105,863.7	5,292.3	111,156.0	24,140.4	23,662.0	47,802.4	158,958.4

[1]Includes estuarine deepwater, and all riverine and marine systems.
Source: USDA NRCS 2000.

Appendix 4–C. Wetland losses in the Northern United States, 1780–1980

State	Estimated wetland circa 1780	National wetlands inventory 1980	Change
	--------Thousand acres--------		Percent
Connecticut	670	173	-74
Delaware	480	223	-54
Illinois	8,212	1,255	-85
Indiana	5,600	751	-87
Iowa	4,000	422	-89
Maine	6,460	5,199	-19
Maryland	1,650	440	-73
Massachusetts	818	588	-28
Michigan	11,200	5,583	-50
Minnesota	15,070	8,700	-42
Missouri	4,844	643	-87
New Hampshire	220	200	-9
New Jersey	1,500	916	-39
New York	2,562	1,025	-60
Ohio	5,000	483	-90
Pennsylvania	1,127	499	-56
Rhode Island	103	65	-37
Vermont	341	220	-35
West Virginia	134	102	-24
Wisconsin	9,800	5,331	-46
Total	**79,791**	**32,818**	**-59**

Source: Dahl 1990.

Appendix 4–D. Tree cover in metropolitan and urban areas in the Northern United States

State	Percentage of State in:		Percentage of tree cover in:		Percentage of State tree cover in:	
	Metropolitan areas	Urban areas	Metropolitan areas	Urban areas	Metropolitan areas	Urban areas
Connecticut	73.6	28.5	39.1	21.8	65.2	14
Delaware	52.0	8.8	50.9	46.3	58.2	9.0
Illinois	32.3	6.1	38.6	33.7	33.0	5.5
Indiana	38.5	5.3	36.5	31.2	35.7	4.2
Iowa	11.7	2.2	36.7	33.1	11.5	1.9
Maine	14.9	3.1	64.7	47.7	14.0	2.2
Maryland	57.1	14.1	46.5	40.1	53.2	11.1
Massachusetts	85.6	25.2	45.1	25.3	88.4	14.4
Michigan	21.9	3.0	37.4	29.7	15.0	1.6
Minnesota	20.7	3.0	50.0	37.4	20.2	2.2
Missouri	17.6	3.1	36.1	30.6	15.3	2.3
New Hampshire	22.1	6.9	58.8	49.1	17.7	4.6
New Jersey	100.0	30.6	56.6	41.4	100.0	22.3
New York	51.6	7.2	44.7	26.3	43.9	3.5
Ohio	47.5	8.5	44.7	38.3	45.6	7.0
Pennsylvania	48.9	7.0	48.7	34.4	43.5	4.2
Rhode Island	79.7	23.2	38.3	8.9	88.9	6.0
Vermont	15.7	1.7	48.9	36.0	10.5	0.8
West Virginia	16.1	1.7	65.6	42.2	13.4	0.9
Wisconsin	25.8	2.7	39.0	25.8	21.8	1.5
All United States	24.5	3.5	33.4	27.1	24.5	2.7

Source: Dwyer and others 2000.

Criterion 5

Maintenance of Forest Contributions to Global Carbon Cycles

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Criterion 5. Maintenance of Forest Contributions to Global Carbon Cycles

LINDA S. HEATH[1]

Carbon is a forest sustainability issue because increasing carbon-containing gases in the atmosphere may lead to climate change. Atmospheric composition has been altered noticeably by the release of greenhouse gases such as carbon dioxide, methane, and nitrous oxide from fossil fuel emissions generated from activities such as vehicle use and heating buildings, and land-based activities such as land clearing for urban use. Atmospheric carbon dioxide concentration alone has increased from 280 parts per million volume (ppmv) in the 18th century to about 360 ppmv in 1994 (Houghton and others 1996). Projections for the year 2070 range from 500 ppmv for an optimistic scenario to 700 ppmv for a high fossil-fuel-emission scenario (Wigley and Raper 1992). Figure 5.1 displays projected levels for the 21st century based on a scenario of existing policies. All greenhouse gases are expected to warm the earth by allowing sunlight to reach the earth's surface, but by blocking generated heat from escaping the atmosphere, some of the gases also act to thin the ozone layer, which shields the earth from harmful solar radiation. General scientific consensus is that under an existing-policies scenario, global mean temperature will increase above the present value by about 1 ºC by 2025 and 3 ºC by 2100 (Houghton and others 1996).

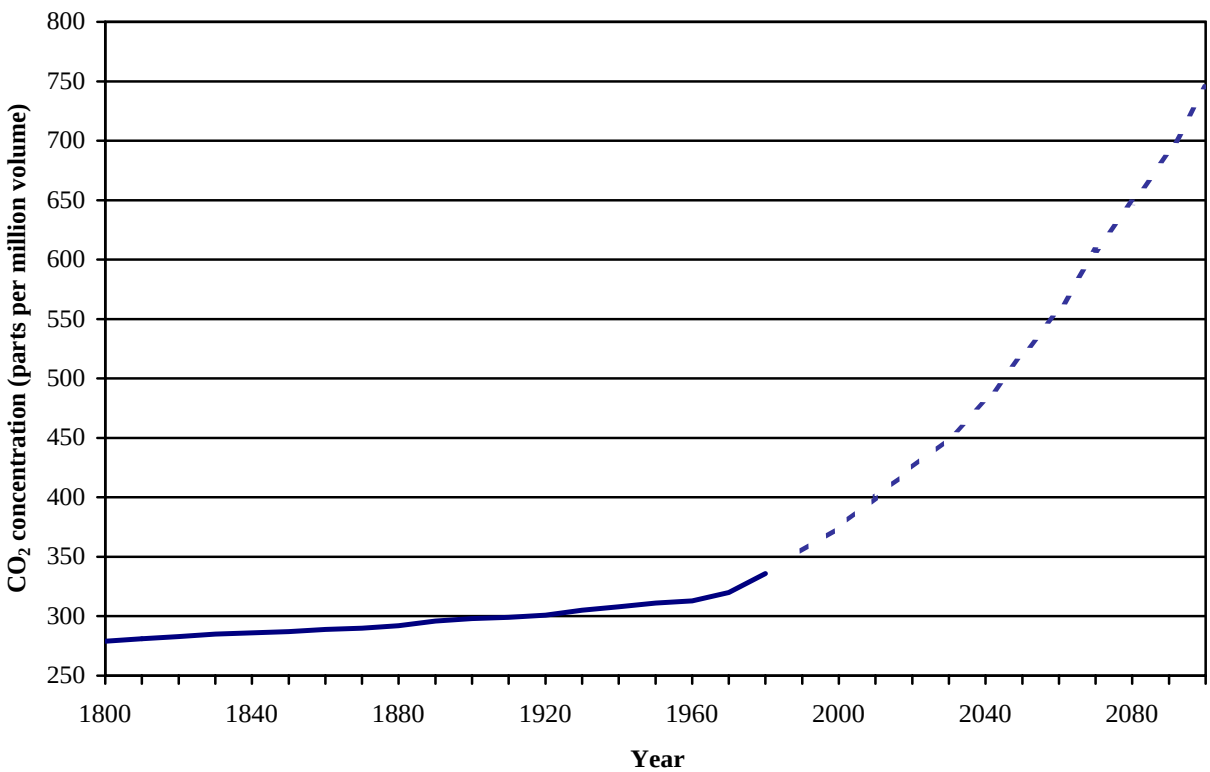

Figure 5.1. **Historical annual estimates and a projection based on a scenario of existing policies of atmospheric CO_2 concentration** (Houghton and others 1996, Wigley and Raper 1992).

[1]USDA Forest Service, Northeastern Research Station, Durham, NH

Growing forests naturally store carbon, and the carbon remains stored in the wood after it is processed into products. The process of storing carbon is called **carbon sequestration**. In general, forest activities such as tree planting increase carbon sequestration, and activities such as prescribed burning release carbon to the atmosphere. Policymakers encourage forest management options for carbon sequestration because increasing forest carbon tends to be an inexpensive way to mitigate increasing atmospheric greenhouse gases. There are three indicators for carbon: the inventory of carbon in forests; the change in forest carbon inventory, called **carbon flux**; and the inventory of carbon in wood products. Tracking carbon in forests will help scientists study the global carbon cycle and will verify the results of adopted mitigation measures. For more information about carbon in forests as an issue, see Heath and Joyce (1997).

Indicator 26. Total forest ecosystem biomass and carbon pool, and if appropriate, by forest type, age class, and successional stages

Indicator 2 (criterion 1) discusses the extent of area by forest type and age class or successional stage. **Total forest ecosystem biomass** includes the main stem of larger trees (the part of the tree that would be removed from the forest if harvested), bark, branches and foliage, stump and roots, small trees called saplings, and dead trees. Multiplying area of forest by the carbon per area estimated for forest types and age classes gives the total ecosystem biomass. The **forest carbon pool** includes carbon in all vegetation, litter, organic debris, and soil. Older forest stands contain more carbon than do younger stands. Forest land area is correlated with total forest ecosystem biomass; therefore, the trend in total forest ecosystem biomass is similar to the area information in indicator 2, and it is not repeated here. Figure 5.2 illustrates regional estimates of forest carbon per hectare on fully stocked timberland for the maple-beech-birch forest type, as the forest grows back after final clearcut harvest.

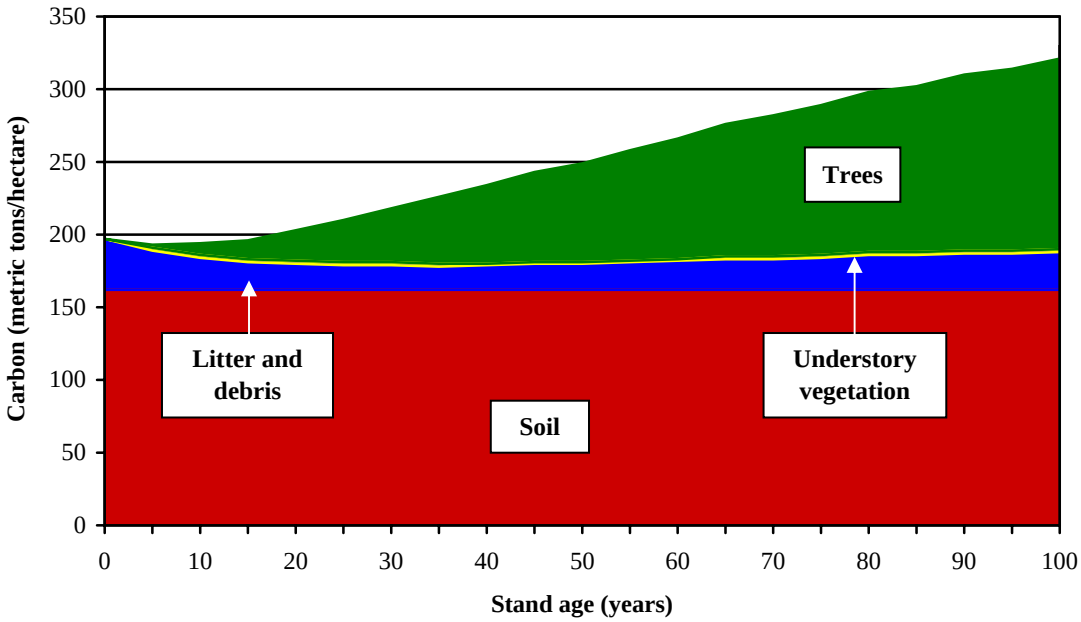

Figure 5.2. **Estimated forest carbon stores in a maple-beech-birch forest type in the Northern United States** (on fully stocked timberland under average management after final clearcut harvest) (data from Birdsey 1996).

Trees are about 50 percent carbon, so the amount of carbon in a forest can be directly calculated by multiplying biomass in terms of dry weight by 0.5. In Northern U.S. forests, biomass in standing large trees is about 2,920 million tons, biomass in stumps and roots is about 1,166 million tons, and biomass in saplings is 1,074 million tons (figure 5.3) (McWilliams and others 2000). Overall, only about 40 percent of the standing tree biomass is in the main stem of trees greater than 12.5 cm diameter at breast height. Eighty percent of the biomass in Northern U.S. forests is in hardwood species.

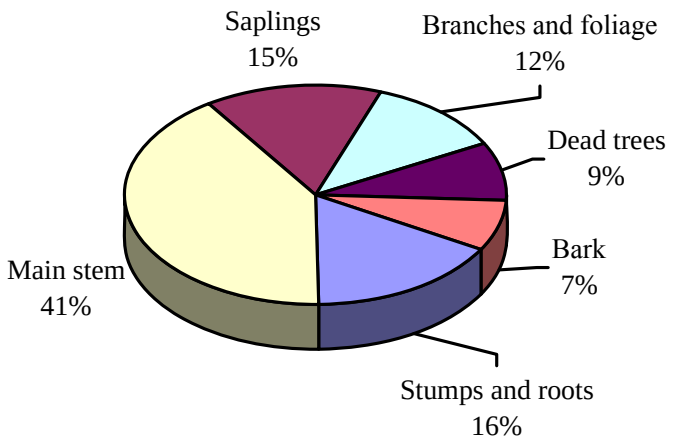

Figure 5.3. **Estimated distribution of biomass for trees in Northern U.S. forests, 1997** (McWilliams and others 2000).

Indicator 27. 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)

Northern U.S. forests are estimated to contain more carbon than forests of the Southern and Western regions of the United States and are projected to continue to contain more carbon under a business-as-usual scenario (figure 5.4) (Birdsey and Heath 1995, Haynes and others 1995). Although Northern forests generally do not grow as fast as Southern forests, they are also not harvested as heavily, which leads to the increases in carbon inventory. In 1992, the soil carbon and litter layer component of Northern U.S. forests was approximately 63 percent of the total carbon pool.

The change, or flux, in carbon over time is expressed as a periodic annual average of million metric tons/year. It is calculated by subtracting adjacent inventories and dividing the difference by the length of time. In 1992, Northern U.S. forests contributed two-thirds of the total carbon flux of U.S. forests (figure 5.5).

Indicator 28. Contribution of forest products to the global carbon budget

Carbon from forests can remain stored in forest products long after forests are harvested and the wood processed into products. Carbon stored in trees harvested in the early 1900s is still stored as wood in houses built then. Harvested carbon can be tracked in four general categories: wood products, landfills, wood burned for energy (which substitutes for fossil fuel), and carbon emitted from wood that is not used as an energy source. The carbon flux from harvesting in Northern U.S. forests in 1990 is illustrated by products, landfills, energy, and emissions, in figure 5.6. By the year 2030, carbon fluxes in the four categories are projected to be 11.4, 10.0, -22.2, and -15.8 million tons per year, respectively.

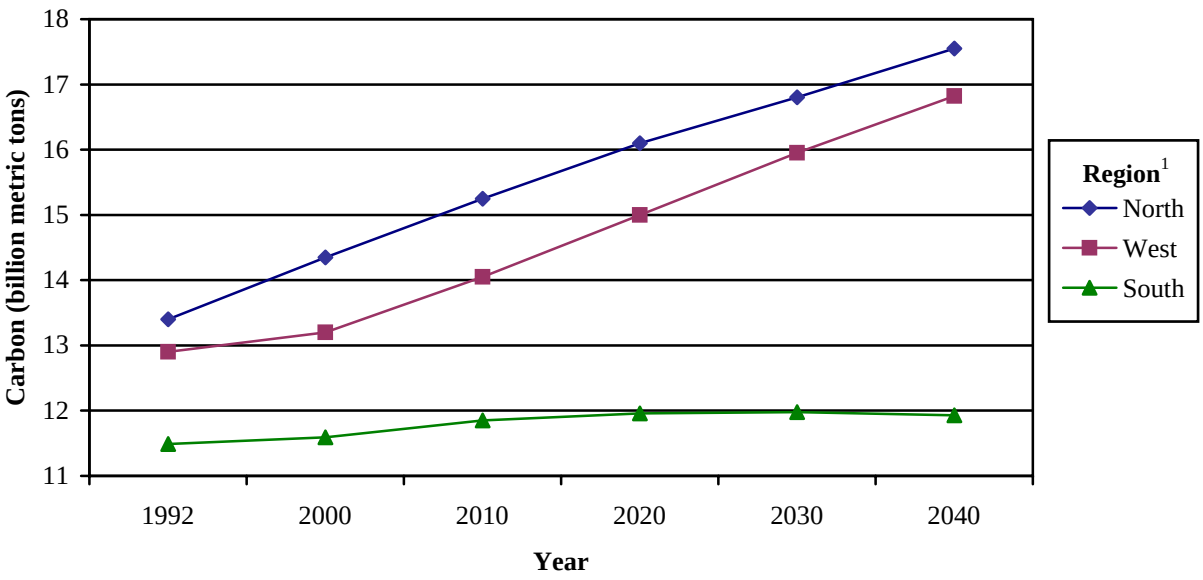

Figure 5.4. **Forest carbon inventory projections by regions of the conterminous United States** (Birdsey and Heath 1995).

[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

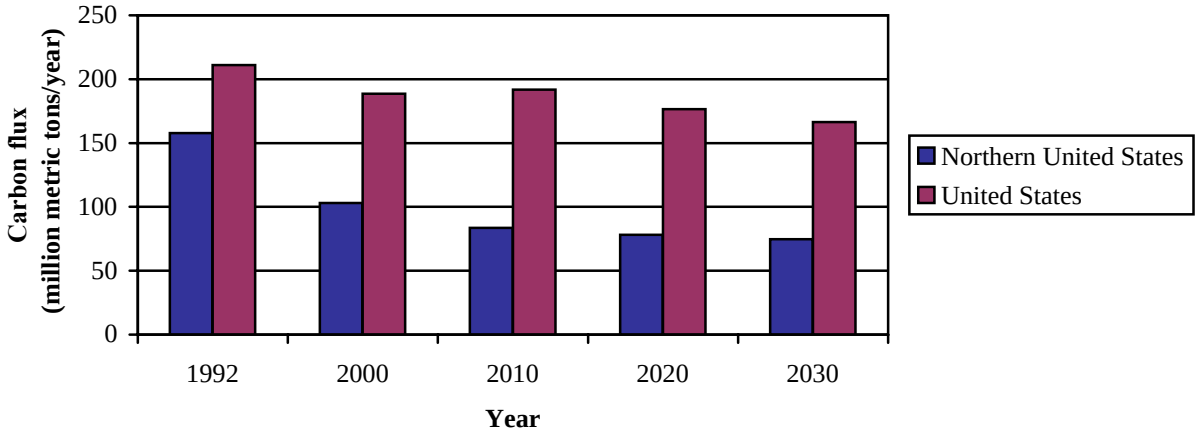

Figure 5.5. **Projected periodic average annual carbon flux in Northern and all U.S. forests**. Year is the middle year of period (Birdsey and Heath 1995).

Forest Management

The three carbon indicators (26, 27, 28) are highly interrelated and are greatly affected by forest management and utilization standards. For instance, increased harvesting tends to lower the proportion of total carbon stored in forest ecosystems (indicator 27), while increasing the proportion of carbon stored in forest products (indicator 28). However, the exact effect that forest management has on the carbon indicators depends on forest area, growth rates, previous land use, the temporal dynamics of stands across the landscape, and other factors.

It is difficult to calculate carbon storage on a per stand basis. Forest management choices affect carbon storage attributed to the stand, and the ultimate use of wood harvested from that stand will also affect its overall contribution. In the example shown in figure 5.7, the carbon stored in the unharvested stand is greater than in the harvested stand with or without considering storage in wood products. Carbon from some harvested wood is also stored in landfills; if this category were added, the storage attributed to the harvested stand would be much greater than shown. Of course, if harvested wood is burned for energy production, the carbon contained in it is no longer stored. The pattern of carbon storage on a per stand basis looks quite different when viewed over time in terms of flux (figure 5.8). Note that at times, carbon stored in the harvested stand plus wood products is estimated to be greater than carbon stored in the stand that is not harvested. It is this type of temporal dynamic that makes it difficult to generalize advice for maximizing carbon storage for the Northern United States as a whole. Individual landowners may choose to maximize the carbon stored on their forest lands by not harvesting, but this strategy will probably result in other forest lands being harvested faster to provide wood to meet consumer demand.

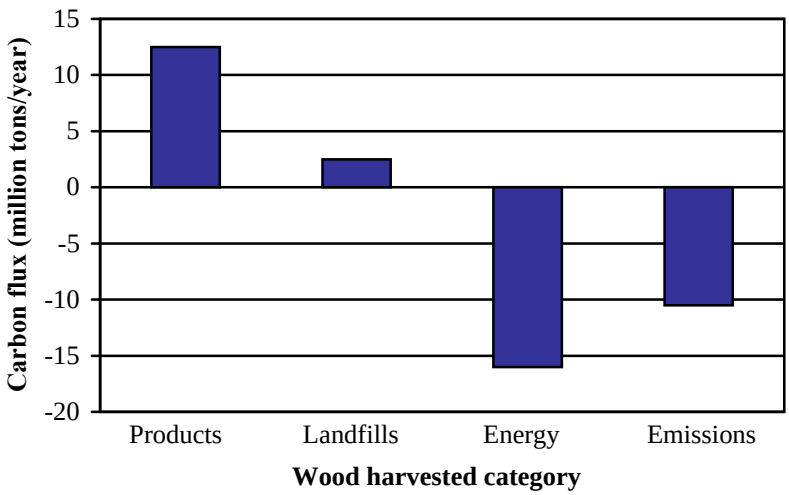

Figure 5.6. **Estimated average annual carbon flux in wood products processed from wood harvested from Northern U.S. forests by category, 1980–1990**. Negative carbon change indicates release of carbon into the atmosphere (Heath and others 1996).

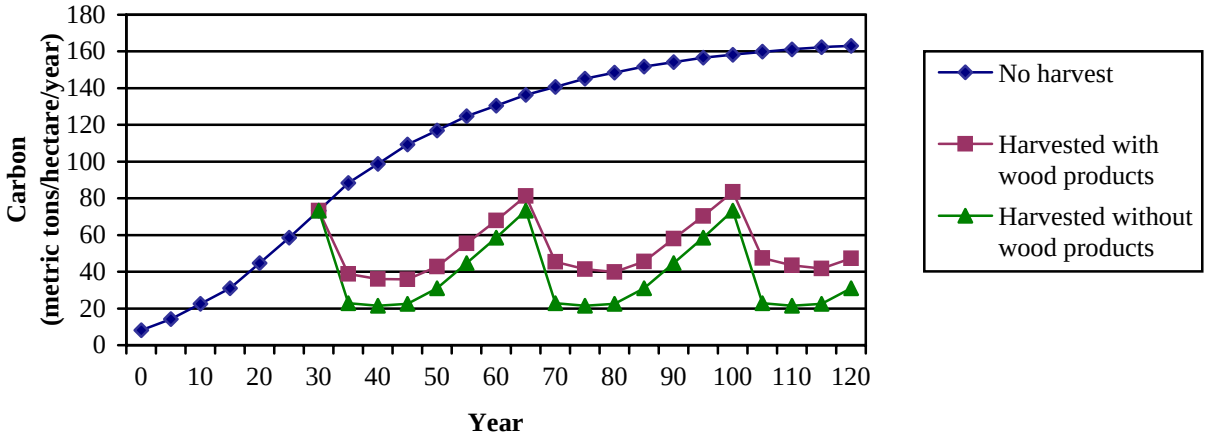

Figure 5.7. **Carbon inventory in average aspen-birch stands, one not harvested and the others harvested at 35-year intervals, with and without carbon stored in wood products** (Birdsey 1996).

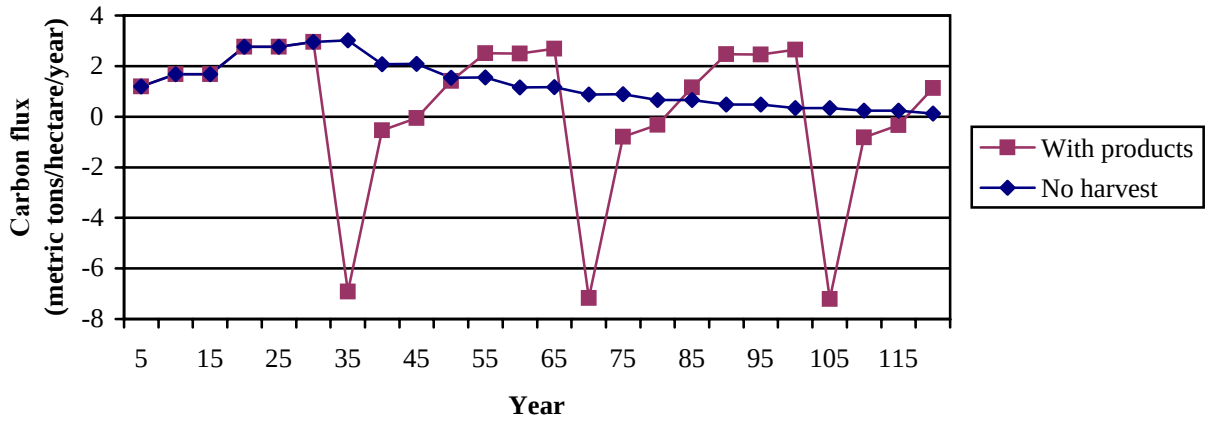

Figure 5.8. **Carbon flux of average aspen-birch stands, one not harvested and the other harvested at 35-year intervals, including carbon stored in wood products**. Carbon inventory is shown in figure 5.7 (Birdsey 1996).

The northern forest landscape features nine major forest type groups (see table 1.2). Over half of the carbon is stored in maple-beech-birch or oak-hickory forests (figure 5.9). Hardwood types contain more carbon than softwoods because they cover more area.

Carbon Management

The Kyoto Protocol, negotiated among parties to the United Nations Framework Convention on Climate Change in December 1997, set forth a framework to reduce greenhouse gas emissions by setting emissions targets, timetables, and market-based measures. Although the protocol has not been ratified by the United States, there is much discussion about the buying and selling of "carbon credits." For instance, landowners who grow trees may be granted carbon credits because these trees are sequestering carbon, and a utility company may pay the landowner for the carbon credits to make up for the amount of carbon the company is emitting in its power plant. Already a voluntary program exists in the United States to track credits on activities including tree planting and forest conservation (U.S. Department of Energy, Energy Information Administration, see http://www.eia.doe.gov/oiaf/1605/frntvrgg.html).

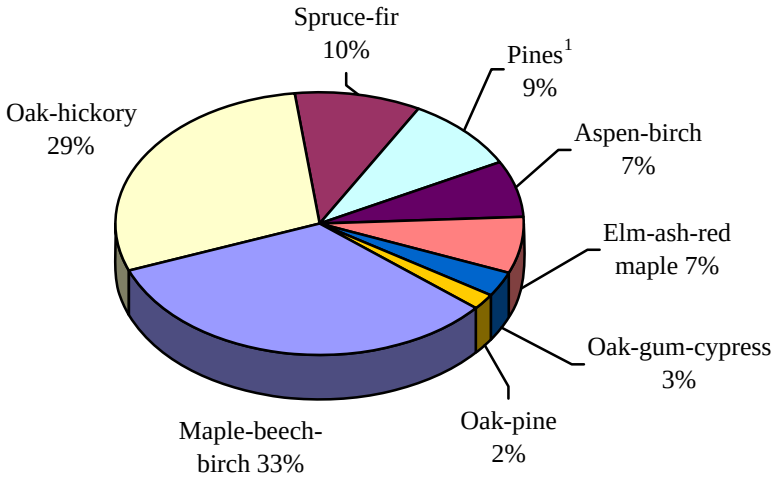

Figure 5.9. **Percentage of carbon in each forest type in privately owned productive Northern U.S. forests** (Birdsey 1996).

[1]Pines include the white-red-jack pine and loblolly-shortleaf pine cover type groups.

Summary and Conclusions

Forests of the Northern United States are storing more carbon than forests of any other region of the United States, and they are projected to continue storing carbon. Currently, most of the carbon is stored in hardwood forest types. Additional carbon is stored in harvested wood that is processed or manufactured into products. The carbon stored in forests mitigates the amount of carbon released into the atmosphere, which may help delay global climate change.

Criterion 6

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

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

Mary Carol Koester,[1] Deirdre Raimo,[2] Susan Lacy,[1] Peter Ince,[3] and Constance Carpenter[2]

The social and economic outputs of forests are both qualitative and quantitative measures of sustainability. The indicators for criterion 6 tell not only the extent to which forests are valued economically, but also how important they are in meeting recreational, cultural, social, and spiritual needs. Tracking the diverse values of forests, as well as the shifts in demand for products and services, can provide insights for the future. This criterion can indicate potential drains on the forest resource and opportunities for management. Although market forces are expected to be the dominant influence on shifting demand for resource-based goods and services, nonmarket forces—such as the desire to sustain biological diversity or the opportunity to dwell in or visit a natural place—will remain critical factors.

The Northern United States has a finite land base of 413 million acres. Although forested area has increased since the 1950s to 169 million acres, it is approaching a leveling-off point. Given a population of 121 million people in 2000, there are 3.7 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. For example, where timber and mushrooms are produced concurrently, timber removal methods may be modified to maintain shade and moisture regimes as well as intact woody debris beneficial to mushrooms on the forest floor. However, there will always be situations where multiple activities and desired uses are incompatible.

Production and Consumption

Production of wood and nonwood products is dependent upon the supply of raw materials, the demand for finished products, and the capability to process the raw materials into desired products. Consumption varies owing to changes in the available supplies of a resource, the efficiency of production methods, and people's willingness and ability to pay for a product.

Over time, these levels change in response to dynamic biological, economic, and social factors. For example, when substitute products replace a forest product, demand may shift, restoring—or, perhaps, eliminating—economic or social returns to the forest owner or product manufacturer.

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[3]USDA Forest Service, Forest Products Laboratory, Madison, WI

Indicator 29. Value and volume of wood and wood products production, including value added through downstream processing

Wood Removals

In 1996, wood removals from timberland growing stock and other sources in the Northern United States totaled nearly 5.1 billion cubic feet (bcf)—78 percent of which consisted of hardwoods (Smith and others 2001) (appendix 6–A). 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 6.1). **Roundwood** refers to wood suitable for primary forest products such as sawlogs, veneer, posts, pulpwood, and firewood. Twenty-four percent of the Nation's wood volume and 21 percent of total roundwood volume originates in the Northern United States.

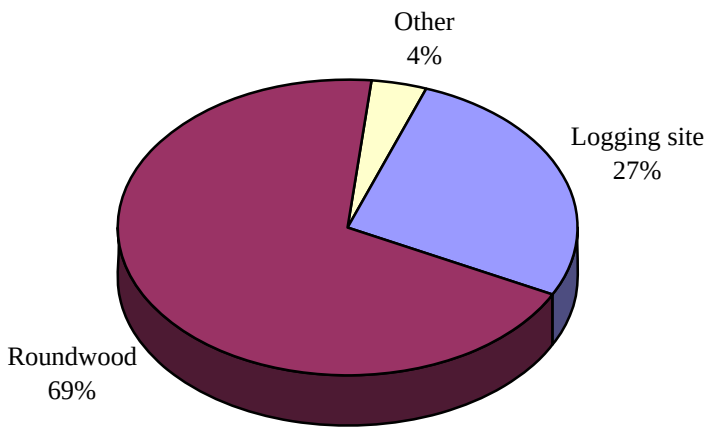

Figure 6.1. **Disposition of wood removals in the Northern United States, 1996** (Smith and others 2001).

Timber Products Output

In 1996, 3.5 bcf of roundwood products were harvested in the Northern United States—the majority (77 percent) from hardwood species (figure 6.2). The top three roundwood products are sawlogs (36 percent), pulpwood (30 percent), and fuelwood (24 percent). Roundwood used for composite products accounts for 6 percent of the total. Nearly equal amounts of wood are harvested in the Northeastern States and the North Central States, but about two-thirds

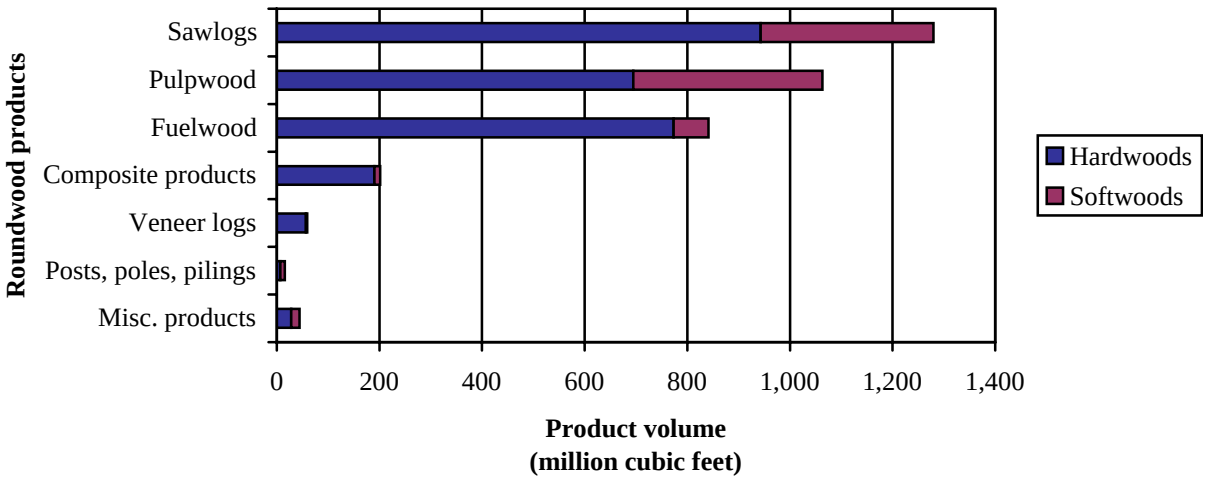

Figure 6.2. **Volume of roundwood products harvested in the Northern United States by species group, 1996** (Smith and others 2001).

(67 percent) of the softwood products come from the Northeastern States (Smith and others 2001). Sixty-five percent of the pulpwood volume comes from hardwoods, significantly higher than the national average of 43 percent (Smith and others 2001).

Most roundwood is harvested from growing stock on timberland (appendix 6–B). Examples of other sources include wood from sound dead trees, trees affected by rot, or trees located in fencerows, windbreaks, wooded strips, and pastures. Black walnut (*Juglans nigra*) trees in these situations, for example, can produce substantial economic returns. Firewood is harvested predominantly from other sources. Less than 15 percent of the firewood harvested in the Northern United States comes from growing stock (figure 6.3).

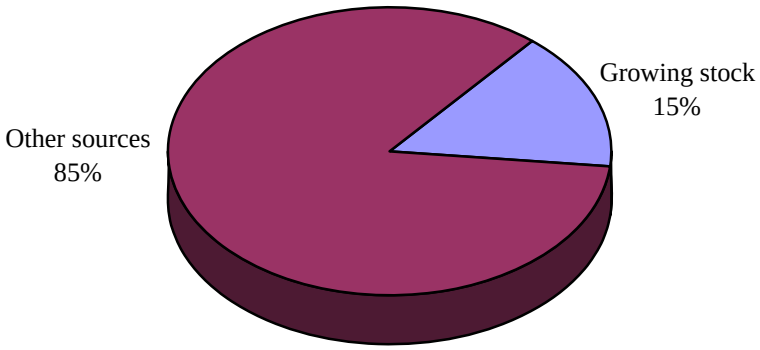

Figure 6.3. **Sources of fuelwood in the Northern United States, 1996** (Smith and others 2001).

In the next 40 years, the Eastern forests, the combined North and South, are expected to contribute a large share of the U.S. harvest—69 percent by 2040. Hardwoods are expected to increase in importance relative to softwoods in total U.S. harvest, as a result of increased use in lumber, fiber products, and fuelwood. The North will play a larger role in the supply of pulpwood and composites such as oriented strand board and waferboard. Lumber production in the Northern United States is expected to remain fairly stable (Haynes 1990).

Increasing suburbanization may further affect the future supply of timber. A recent study in Virginia found that the probability of forest management approaches zero at approximately 150 people per square mile (psm). At 70 people psm there is a 25 percent chance that commercial forestry will be practiced, at 45 people psm there is a 50 percent chance, and at 20 people psm there is a 75 percent chance. Estimates in the study area indicate the actual available timber supply may be 40 percent less than the current estimate, which is based on land area and growing stock. This comparison implies estimates of available timber in other States could be overstated if based on the common definition of timberland. A replication of the study in the Northern United States would either corroborate the finding or provide a more site-specific estimate. This comparison also indicates that linking social data to forest inventory would provide a more accurate figure for timber supply (Wear and others 1999).

It remains unclear how nonindustrial owners in the North will respond to rising inventories and prices for hardwoods. A recent study suggests that, despite increasing incentives, owners will not respond with much of an increase in their harvest. This projected outcome is based on a diverse ownership structure and ownership objectives that deemphasize income production from timber harvest. Timber prices will continue to motivate many landowners; however, other social and demographic factors may interrupt the expected market response.

Value of Wood and Wood Production

Forests in the Northern United States are dynamic systems containing a large variety of tree species. In addition, the condition of the trees varies, which has considerable bearing on their value for use in wood products. The cost of a log includes the value of the standing tree and all labor, transportation, and processing costs necessary to create a desired product, such as a piece of fine furniture or a cardboard box.

Timber harvest and processing industries also provide an indirect value to communities through income generation and economic diversity. The **timber processing industries** are combined into three product groups: wood product manufacturing, wood furniture manufacturing, and paper manufacturing. When a tree is harvested, its species and quality determine how it will be processed. Premium logs are used for furniture, paneling, and plywood, whereas those of average to good quality are processed into construction lumber or pallets. Poles are used for pilings and posts, or chipped and converted to pulp and paper.

The economic contributions of the timber harvest and processing industries in the Northern United States are listed in table 6.1. This region has over 15,500 companies harvesting roundwood and manufacturing lumber, furniture, and paper, and over 3,100 logging companies. The value of shipments exceeds $111 billion. The value added to the raw materials through manufacturing exceeds $52.5 billion (USDC Bureau of the Census 2002).

Table 6.1. **Major timber harvesting and processing industries in the Northern United States** (USDC Bureau of the Census 2002).

Industry type	Number of establishments	Value added	Total value of shipments
		---Thousand dollars---	
Logging	3,108	801,326	1,787,636
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	**18,990**	**52,523,914**	**111,516,236**

Whereas all States in the Northern United States have some degree of timber processing, a few are leaders in the three industry components. Based on the 1997 value of shipments, Indiana, Michigan, Minnesota, Ohio, Pennsylvania, and Wisconsin contribute 65 percent in the wood products industries. Among the wood furniture industries, Indiana and Ohio each ship over $1.6 billion, which together are nearly one-third of the regional total. Six States (Illinois, Michigan, New York, Ohio, Pennsylvania, and Wisconsin) lead the region in the value of shipments in the paper products industries with a combined total of $44.3 billion, or 61 percent of the regional total (USDC Bureau of the Census 2002) (appendixes 6–C through 6–F).

Indicator 30. Value and quantities of production of nonwood forest products

Nonwood forest products, often called **special forest products**, are forest outputs that have a value but do not come from the trunk of a tree. Currently, the Northern United States does not maintain a comprehensive listing of nonwood forest products, but the number of products is high. In one regional study, 138 special forest products were identified (Emery 1999). Nonwood products include aromatic compounds, berries and wild fruits, cones and seeds, forest botanicals, honey, mushrooms, nuts, syrup, weaving materials, and dyes. Uses for these products include flavorings, medicines, greenery, transplants, florals, and edibles (Thomas and Schumann 1993).

Nonwood forest products have been gathered for centuries. Recently, however, their social and economic value has brought them to the attention of traditional forest managers. The challenge for managers is to discern the appropriate balance among biological, ecological, and social factors to ensure sustainable harvests. For example, in addition to quantitative market values, special forest products have qualitative cultural and social values for families and communities (figure 6.4). Gatherers can simultaneously earn needed income, communicate knowledge and practices to descendants, and derive pleasure from the journey to the woods as well as the consumption of the product. In the Upper Peninsula of Michigan, craft and decorative products are the most frequent source of cash income, although edibles are also gathered for market uses (Emery 1999).

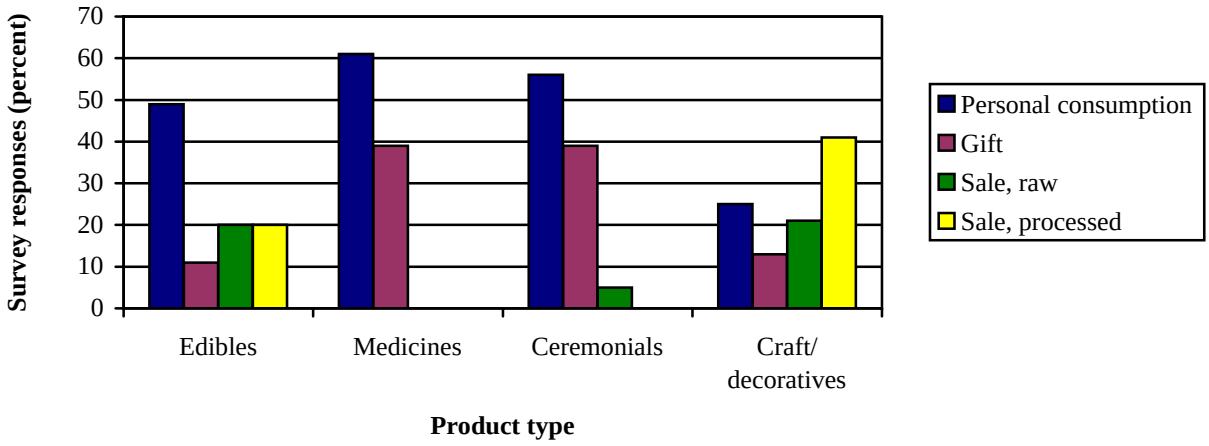

Figure 6.4. **Use of specialty forest products in the Upper Peninsula of Michigan**. Gatherers use specialty forest products for personal consumption and gifts, and for sale in raw and processed forms (Emery 1999).

The contribution of many nonwood forest products to local or regional economies is not well measured, but it can be significant. Traditionally, the in situ value of the raw material of nonwood forest products is not assigned a value or measure. The market value is derived mostly from the cost of collecting and processing the product. Capital expenditures are low in traditional operations, but maintenance of social capital is a necessity for ensuring steady supplies. Cultivation and commercialization are beginning to play a larger role in the production and consumption of nonwood forest products.

Maple Syrup

The maple syrup industry is a significant portion of some State economies in the Northern United States. Records of production and value of this nonwood product are maintained by States and compiled by the North American Maple Project. Ten of the 20 Northern States contribute an average of $34 million to the regional economy each year through maple syrup production (USDA National Agricultural Statistics Service 1995–1999) (table 6.2).

Table 6.2. **Maple syrup production in the Northern United States, 1994–1998** (USDA National Agricultural Statistics Service 1995–1999).

State	1994	1995	1996	1997	1998
			Thousand dollars		
Connecticut	471	281	427	375	370
Maine	2,145	2,965	3,657	3,663	3,502
Massachusetts	1,456	1,105	1,906	1,637	1,701
Michigan	2,491	1,480	2,737	2,363	1,760
New Hampshire	2,540	2,413	3,311	3,055	2,425
New York	6,150	4,888	8,747	6,752	6,202
Ohio	2,340	1,872	2,565	2,926	324
Pennsylvania	1,528	1,079	1,747	1,638	1,872
Vermont	10,397	10,147	14,575	10,902	10,440
Wisconsin	2,730	2,489	2,497	1,905	1,617
Total	**32,248**	**28,719**	**42,169**	**35,216**	**32,213**

The total contribution of the maple syrup industry is even greater when suppliers, tourism, and other values are considered, although these are not routinely and systematically measured across States. However, various entities in Vermont, Massachusetts, and New Hampshire collect variable data on direct and indirect economic contributions of the industry (table 6.3).

Table 6.3. **Maple syrup industry annual contributions to the economy** (Cooke 2000, USDA National Agricultural Statistics Service 1995–1999).

Maple syrup industry contribution	Amount
Vermont	
Bulk prices to farmers	$10 million
Equipment manufacturing	$5 million
Container manufacturing	$5 million
Syrup packing and wholesaling	$70 million
Retail gift shop/mail order	$15 million
Jobs	4,000
Stumpage	$9 million
Lumber sales	$36 million
Massachusetts	
Syrup sales	$2 million
Container manufacturing	$2 million
60,000 visitors to sugarhouses	$1 million
Open space preserved	over 8,000 acres
New Hampshire	
Syrup sales	$3 million
Value of open space	$1,500/acre/year
Forestry	$3.9 billion
Tourism/recreation	$3 billion

Other Nonwood Forest Products

Forests contain a wide variety of plants collected for flavorings and medicines. Essential oils are at the core of the $10 billion U.S. food flavorings and cosmetics industries. Cedar oil was selling at about $9.50 per pound in 1978, although the market can fluctuate widely. Various estimates of production in the United States and Canada are listed in table 6.4 (Thomas and Schumann 1993).

Table 6.4. **Production of selected essential oils in the United States and Canada** (Thomas and Schumann 1993).

Essential oil	Production
	Metric tons
1979	
Hemlock oil	0.45–0.91
Spruce oil	1.81–2.27
Sweet birch oil	2.49
Wintergreen oil	1.13
1984	
Cedar leaf oil	25
Fir balsam oil	10
Cedarwood oil, Virginia	240
Cedarwood oil, Texas	1,400

Botanicals used as natural food preservatives are expected to become more important in the future. Some botanicals possess specific physical chemistries that have medical application. Although most of the estimated 100 tons of goldenseal root is harvested annually from eastern deciduous forests, a cultivation operation in Iowa now makes up for the increasing pressure on wild populations. The largest growing area for the $50 million American ginseng crop is Marathon County, Wisconsin (Foster 1997).

Demand for native species from Missouri in 1993 (Mater Engineering 1993) was as follows:

- Witch hazel (*Hamamelis virginiana*) 110,000 lb
- Purple cone flower (*Echinacea purpurea*) 65,000 lb
- Black walnut hulls (*Juglans nigra*) 200,000 lb
- Ginseng (*Panax quinquefolium*) 230,000 lb
- Goldenseal (*Hydrastis canadensis*) 275,000 lb
- Mayapple (*Podophyllum peltatum*) 220,000 lb
- Slippery elm (*Ulmus rubra*) 200,000 lb

Tree cones are used for floral, wreath, and potpourri products and are gathered for seeds for tree planting and nursery operations. Decorative cone sales are highest in Minnesota and the East Coast States. Prices for decorative cones typically range from 37 to 52 cents per semidry pound; however, trailer loads (about 2,400 bushels) can cost only a few cents per cone and are wholesaled in 2,000- to 20,000-pound increments. A medium-sized company buying cones for holiday gift packs may purchase 30 trailers of cones a year (72,000 bushels) at between $0.50 and $1.50 per bushel.

In Wisconsin, fall cone prices in 1991 were $2.50 per bushel for white spruce (*Picea glauca*), $1.75 per bushel for red pine (*Pinus resinosa*), $1.50 per bushel for Norway spruce (*Picea abies*), $0.50 per bushel for black spruce (*Picea mariana*), and $1 per pound for tamarack (*Larix laricina*) cones. In Minnesota, cones usually sell for about $2 per bushel. Seed cones command higher prices: in 1991, prices in New York State were $7 per bushel for white pine

(*Pinus strobus*), $18 per bushel for red pine, $22 per bushel for tamarack, and $24 per bushel for balsam fir (*Abies balsamea*) seed cones.

In Minnesota, the wreath and bough business is estimated at $10 million in sales for both commercial and individual entrepreneurs. In the upper Midwest, birch (*Betula* spp.), ironwood (*Ostrya virginiana*), and alder tops (*Alnus* spp.) are used as decorative "lifelike trees" in shopping malls and hotel lobbies. Estimated production is 80,000 to 100,000 trees annually.

Production values collected on the west coast serve as a regional indication of the production of greens in the United States. In 1989, a survey on the west coast estimated collection (production) as follows:

- 12.8 million bunches of beargrass (*Xerophyllum tenax*) worth $11.5 million
- 3.4 million bunches of baby's breath (*Gypsophila muralis*) worth $5 million
- 2.7 million bunches of evergreen huckleberry (*Vaccinium ovatum*) worth $1.7 million
- 2.5 million bunches of swordfern (*Polystichum munitum*) worth $1.5 million

In addition, evergreen boughs were estimated at $12.6 million. Overall, the value of floral greens was estimated at $35.1 million (Blatner 1997).

Another partial measure of production is the value of special forest products removed from national forest land. Christmas trees, greens, cones, fruits, nuts, sap, roots, mushrooms, and other plants were valued per fiscal year at $2.97 million in 1998, $2.76 million in 1999, and $2.91 million in 2000 (USDA Forest Service 2000c).

Some national forests in the Northern United States have adopted permit fees of a fixed amount for gathering commercial greens and cones (USDA Forest Service 1997c) (table 6.5). These fees are not required when gathering for personal use.

Berries and wild fruit with commercial potential include blackberry (*Rubus canadensis*), black cherry (*Prunus serotina*), blueberry (*Vaccinium* spp.), chokeberry (*Aronia* spp.), crabapple (*Malus* spp.), currant (*Ribes* spp.), elderberry (*Sambucus canadensis*), gooseberry (*Ribes* spp.), common persimmon (*Diospyros virginiana*), plum (*Prunus americana*), raspberry (*Rubus* spp.), serviceberry (*Amelanchier canadensis*), staghorn sumac (*Rhus typhina*), and strawberry (*Fragaria* spp.) (Thomas and Schumann 1993). Nearly half of the blueberries produced commercially in the United States are from wild bushes. Per capita consumption doubled between 1984 and 1993. Between 1984 and 1988, an average of over 17.5 million kilograms of blueberries were produced in Maine alone, from over 10,000 hectares of land. Maine has had crops of lowbush blueberries approaching 50 million pounds. A survey of northern Minnesota resorts showed that 29 percent of resort visitors picked wild berries for recreation.

Nuts commonly used for food and commercial purposes include beechnut (*Fagus grandifolia*), butternut (*Juglans cinerea*), chestnut (*Castanea dentata*), hickory (*Carya* spp.), pecan (*Carya illinoinensis*), persimmon, and walnut. Black walnut nutmeats sell for $6 per pound, and uncracked walnuts sell for from $0.75 to $1.25 per pound. The shells of black walnuts bring from $60 to $90 per pound.

Table 6.5. **National forest permit fees for nonwood products, 1997** (USDA Forest Service 1997c).

Nonwood product	Market value	USDA Forest Service permit charge
Ottawa National Forest		
Balsam fir boughs	$250/ton	$25/ton
Princess pine	$35/100 lbs	$3.50/100 lbs
Sheet moss/lichen	$50/100 lbs	$5/lb
Closed red/jack pine cones	$10/bushel	$1/bushel
White spruce cones	$12.50/bushel	$1.25/bushel
Hoosier National Forest		
Ginseng	$300–400/lb dried root	
Goldenseal (yellow root)	$30/lb dried root $4/lb dried tops	
Bloodroot	$6.50/lb dried root	$10
Virginia snake root	$20/lb dried root	$10
Black cohosh	$1.65/lb dried root	
Chippewa National Forest		
Balsam fir boughs	$250/ton	$25/ton
Syrup	$3.49/50 lbs	$10/200 taps
Blueberries	$3.50/lb	
Pine cones	$4.99/lb	
Monongahela National Forest		
Ginseng	$300–400/lb dried root	$10 permit/ One 50-lb bag only
Moss	$50/100 lbs	$10 permit plus $0.50/50-lb bag
Princess pine	$35/100 lbs	$10 permit plus $3.50/50-lb bag
Black cohosh	$1.65/lb. dried root	$10 permit/ One 50 lb-bag only

Several Northeastern States are currently marketing several native species in the decorative wood industry, including witch hazel, maple, cherry, chestnut, walnut, redbud (*Cercis canadensis*), and slippery elm (*Ulmus rubra*). The predominant basketmaking materials in the Eastern United States are ash (*Fraxinus* spp.) and white oak (*Quercus alba*) (Thomas and Schumann 1993). The Ojibwa Tribe in Minnesota sells a full line of wood products to high-end retailers, including Bloomingdale's, Nordstrom, and Saks Fifth Avenue (Mater 1997).

Woods used as a natural flavoring in grilling and cooking include alder, apple (*Pyrus* spp.), bigleaf maple (*Acer macrophyllum*), cherry, hickory, oak, and sugar maple (*Acer saccharum*). Annual gross sales in cooking woods are estimated at $18 to $20 million.

Indicator 31. Supply and consumption of wood and wood products, including consumption per capita

Forest products supply and consumption have steadily increased between 1960 and 1990. In the Northern United States, all categories—roundwood, sawnwood, wood-based panels, wood pulp, and paper and paperboard—have shown a marked increase in supply and total

consumption. U.S. per capita consumption of all products has increased, but at slower rates than have total supply and consumption.

The estimated volume of roundwood products harvested in the Northern United States in 1996 was 3.5 bcf (Smith and others 2001). This estimate is consistent with projections from *The 1993 RPA Timber Assessment Update* (Haynes and others 1995) (table 6.6). The assessment indicates that between 1952 and 1991, roundwood supplies for the combined area of the Northern United States and the Great Plains States more than doubled, from 2.18 to 4.62 bcf, with most of the increase coming from hardwood forests (Haynes and others 1995).

Table 6.6. **Roundwood supplies from forest land in the Northern United States and the four Great Plains States (Kansas, Nebraska, North Dakota, and South Dakota)** (Haynes and others 1995, p. 38).

Year	Northeastern States		North Central and Great Plains States		Total
	Softwoods	Hardwoods	Softwoods	Hardwoods	
			Billion cubic feet		
1952	0.48	0.55	0.17	0.98	2.18
1962	0.37	0.55	0.20	0.80	1.92
1970	0.38	0.54	0.17	0.75	1.84
1976	0.43	0.52	0.21	0.81	1.97
1986	0.60	1.52	0.24	1.93	4.29
1991	0.67	1.67	0.27	2.01	4.62
Projections					
2010	0.95	2.18	0.48	2.38	3.13
2020	1.00	2.36	0.51	2.47	3.36
2030	1.01	2.55	0.52	2.58	3.56
2040	1.03	2.82	0.51	2.75	3.85

An estimate of the production of pulpwood, a growth sector, is presented for both hardwoods and softwoods for 11 States—Illinois, Indiana, Iowa, Maine, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Wisconsin—for the years 1965–1997 (figure 6.5). During this 32-year period, total pulpwood production increased from 7.9 million cords to 14.1 million cords (78 percent) (Howard 1999). Pulpwood consumption by the wood pulp industry in the Northern United States and Great Plains States in 1990 was estimated at 1,317 million cords and, according to projections, will increase to 1,990 million cords by 2040 (Haynes 1990). An estimate of the production of lumber in these same States for the years 1965–1997 is presented for hardwoods and softwoods (figure 6.6). Total lumber production, a measure of regional lumber supply (excluding imports and exports), has more than doubled in the past three decades (Howard 1999).

Consumption patterns in the Northern United States likewise showed a steady increase from 1960 to 1990 (table 6.7). In this 30-year period, roundwood consumption increased by approximately 37 percent and sawnwood consumption by 29 percent. Increases in consumption were substantially larger for wood-based panels (149 percent), wood pulp (95 percent), and paper and paperboard (86 percent).

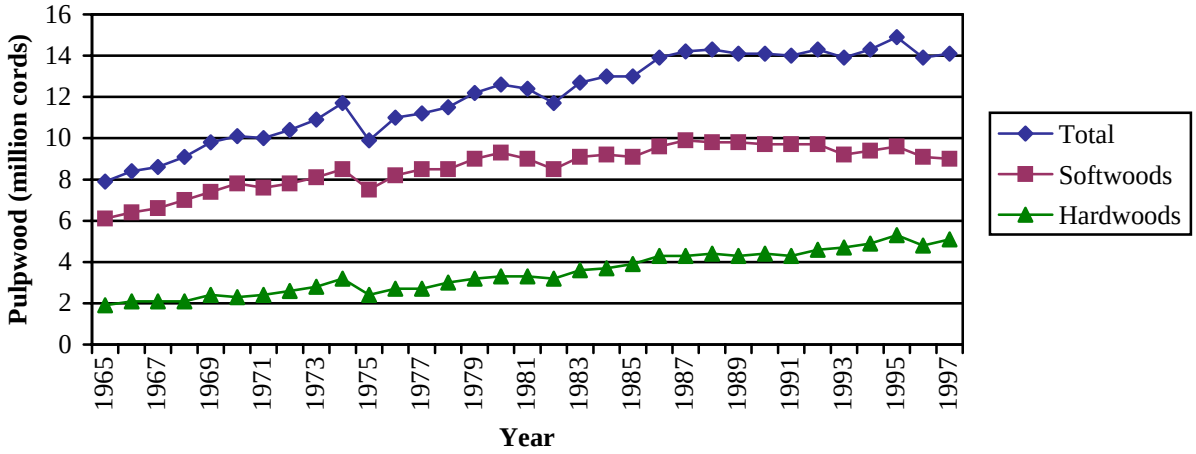

Figure 6.5. **Pulpwood production in 11 Northern States,[1] 1965–1997** (Howard 1999, p. 38).

[1]Illinois, Indiana, Iowa, Maine, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Wisconsin.

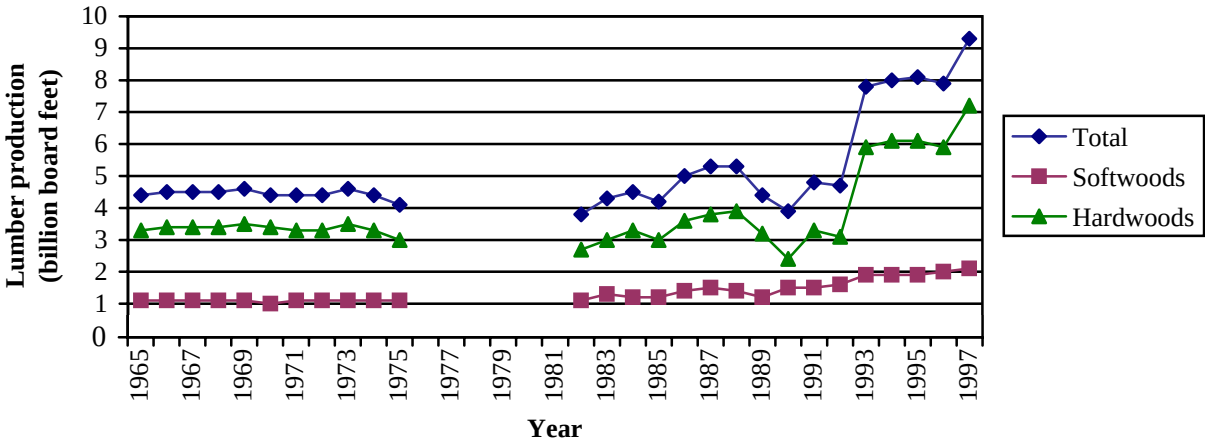

Figure 6.6. **Lumber production in the Northern United States and the four Great Plains States (Kansas, Nebraska, North Dakota, and South Dakota), 1965–1997** (data not available for 1976–1981) (Howard 1999, p. 42).

Consumption per capita has increased by varying amounts among sectors, with roundwood increasing by 20 percent and sawnwood increasing by 13 percent. For wood-based panels, consumption per capita almost doubled; for wood pulp, consumption increased by 70 percent; and for paper and paperboard, consumption increased by 62 percent (USDA Forest Service 1996b).

Consumption, production, trade, and prices for the various classes of forest products are projected to follow somewhat diverse trends over the next five decades, driven, in part, by the effects of material substitution and limited lumber supplies. For example, steel studs are frequently used in home building as a substitute for wood.

Proportionately more useful wood products are being produced from timber harvested today than in the past owing 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 an estimated 92 percent.

Indicator 32. Value of wood and nonwood products production as a percentage of gross domestic product

In the Northeastern United States, wood and nonwood products are an important sector of State economies. Table 6.8 displays only a partial contribution of natural-resource-based sectors (including forestry, fish, and agriculture) and of two wood-based sectors to total State economies (USDC Bureau of Economic Analysis 1998).

A subregional analysis illustrates how important forest industry is in many Northeastern communities. In Maine, New Hampshire, New York, and Vermont in 1987, total wood-based manufacturing contributed $4.9 billion in gross State product. The relative importance of forest-based economic activity is highest in Maine (12 percent) and Vermont (11 percent); it is 7 percent in New Hampshire and 2 percent in New York. Wood processing and paper are critical to the economic base of many communities in the region. In 1982, wood-based manufacturing accounted for 69 percent of all manufacturing jobs in western Maine, 34 percent in northern New Hampshire, and 15 percent in southern Vermont (Northeastern Forest Alliance 1992).

The wood products sector alone does not provide a complete picture of the percentage of gross state product attributed to natural-resource-based sectors. On a conservative basis, State general revenues from forest-based tourism and manufacturing in these four States are estimated at about $204 million. Recreation revenues amount to more than half of this owing to the large revenues generated by State taxes on meals and lodging (Northeastern Forest Alliance 1992).

Table 6.7. **Forest products consumption in the Northern United States and U.S. rate of consumption per capita**[1] (USDA Forest Service 1996b).

Forest products category and year	Estimated consumption for the Northern United States	U.S. rate of consumption per capita
	Thousand cubic meters	
Roundwood		
1960	175,026	1.79
1990	240,148	2.15
Sawnwood		
1960	45,878	0.47
1990	59,260	0.53
Wood-based panels		
1960	4,600	0.05
1990	11,461	0.10
	Metric tons	Kilograms
Wood pulp		
1960	13,013	133
1990	25,326	226
Paper and paperboard		
1960	18,835	426
1990	34,958	689

[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.

Table 6.8. **Selected industry sectors as a percentage of gross state product (GSP)** (USDC Bureau of Economic Analysis 1998).

State	Total GSP, 1998	Agriculture, forestry, and fishing, 1998		Lumber and wood, 1998		Furniture and fixtures, 1998	
	Millions of current $	Millions of current $	% of GSP	Millions of current $	% of GSP	Millions of current $	% of GSP
Connecticut	142,099	923	0.6	223	0.2	156	0.1
District of Columbia	54,100	14	0.0	4	0.0	4	0.0
Delaware	33,735	272	0.8	23	0.1	57	0.2
Iowa	84,628	4,597	5.4	629	0.7	443	0.5
Illinois	425,679	4,835	1.1	639	0.2	955	0.2
Indiana	174,433	2,498	1.4	1,635	0.9	1,332	0.8
Massachusetts	239,379	1,271	0.5	237	0.1	260	0.1
Maryland	164,798	1,283	0.8	186	0.1	134	0.1
Maine	32,318	525	1.6	643	2.0	134	0.4
Michigan	294,505	2,470	0.8	951	0.3	2,964	1.0
Minnesota	161,392	3,294	2.0	1,366	0.8	324	0.2
Missouri	162,772	2,315	1.4	480	0.3	749	0.5
New Hampshire	41,313	267	0.6	264	0.6	67	0.2
New Jersey	319,201	1,567	0.5	213	0.1	390	0.1
New York	706,886	2,806	0.4	704	0.1	805	0.1
Ohio	341,070	3,505	1.0	1,684	0.5	928	0.3
Pennsylvania	364,039	3,045	0.8	1,874	0.5	821	0.2
Rhode Island	30,443	199	0.7	47	0.2	104	0.3
Vermont	16,257	335	2.1	164	1.0	118	0.7
Wisconsin	157,761	3,276	2.1	1,410	0.9	806	0.5
West Virginia	39,938	262	8.2	453	1.1	25	0.1
Total	**3,986,746**	**39,559**	**1.0**	**13,829**	**0.3**	**11,576**	**0.3**

Other wood and nonwood products from the four States include the following (Northeastern Forest Alliance 1992):

- Maple syrup valued at $21.6 million
- Christmas trees valued at $46 million
- Wreaths valued at $11.5 million
- Mushrooms valued at $1.2 million
- Cedar oil valued at $106,250

These products constitute a very small percentage of the gross state product, but their volume and value continue to grow. In 1987, the contribution of nonwood products to national income was estimated at about one-half of 1 percent.

Indicator 33. Degree of recycling of forest products

Nationwide

Nationwide, recycled materials are an economical substitute for wood pulp for a large share of industry. Many papermaking facilities use only recycled fiber, whereas others use a blend of recycled fiber and virgin wood pulp. Use of recycled fiber varies by product grade and depends on product performance requirements and costs. Recycling is highest in product grades such as tissue, newsprint, and boxboard. Recycling in general reflects the value that society places on efficient use of resources. In the United States, paper recycling has increased as pulpwood values have increased in recent decades.

Recycled fiber and pulpwood compete with one another for market share. Changes in supply of one type of fiber material will affect the market for all substitute fibers. As recycled fiber flooded the market in the 1990s, both recycled fiber and pulpwood prices became somewhat depressed. On the other hand, to the extent that recycled fiber is a substitute for virgin wood fiber, use of recycled fiber can have a short-run effect of "conserving" or reducing wood use. In reality, resource development is a dynamic function of market forces and economic conditions, and it is difficult to predict without careful economic analysis exactly how developments such as recycling will affect forest sustainability.

The following forest products are recycled in the United States:

- Paper and paperboard—45.3 million tons were recovered in 1998: 36.3 million tons for recycling back into paper and paperboard products, 1.4 million tons for making other products such as molded pulp and insulation, and 7.6 million tons for net export (AF&PA 1999).
- Wooden pallets—Although precise data are not readily available, it is estimated up to 5 million tons of pallets are recycled each year.
- Smaller amounts of forest products are recovered and recycled in other end uses, including a small amount of pallet lumber and other recycled wood in particleboard plants, and a small amount of wood used in making wood and plastic composites.

Nationwide average utilization rates in 1997 for products produced in the United States from recovered paper are as follows (AF&PA 1999):

- Newsprint (47 percent)
- Tissue paper products (60 percent)
- Boxboard such as used in breakfast cereal boxes, shoe boxes, etc. (typically 100 percent recycled)

Less common recycled products include these:

- Wood and plastic composite lumber (outdoor furnishings and marine applications)
- Hydromulch (seeding and bedding material made from recycled paper)

Northern United States

Demand for paper recycling is higher in the Northern United States than it is nationwide because the region's paper and paperboard industry is geared toward using a higher proportion of recycled fiber than in other regions. The recovered paper utilization rate in the region averaged about 55 percent in 1996, while nationwide the figure was 37 percent (AF&PA 1999). This utilization rate is the ratio of the tons of recovered paper used in paper and paperboard mills relative to the tons of finished products.

In 1995, 14 million tons of paper and paperboard was recycled in the Northern United States (AF&PA 1999). Paper and paperboard mills in the Northern United States consume about 44 percent of the recovered paper used in the United States.

Exports of recovered paper declined, particularly exports to Asia, after reaching a peak in the mid-1990s. This decline contributed to depressed market conditions for recycled products overall. Significant price volatility during that time suggests that an increase in Asian or worldwide demand would increase prices. Prices for recovered paper began to turn upward in 1999 along with some recovery in Asian markets.

The United States is approaching a paper recovery rate of 50 percent for recycling, a rate that corresponds with paper recovery in Japan (52 percent).

One of the greatest technical challenges to using recycled fiber in higher quality printing and writing papers is dealing with "**stickies**," adhesives and plastics contaminants. The cost of stickies removal in high-grade printing and writing paper mills often makes the use of post-consumer wastepaper too costly. Technical solutions include developing contaminant-removal equipment or label adhesives that are more easily separated from paper, such as recyclable self-adhesive postage stamps supported by research at the USDA Forest Service Forest Products Laboratory. Technical solutions to recycling problems such as stickies exist, but the solutions differ in cost and consumer acceptance.

The USDA Forest Service research program aimed at the recycling of forest products is the largest such continuous program among all State and Federal government agencies. The Forest Service program is centered at the Forest Products Laboratory in Madison, Wisconsin.

Use of wood manufacturing byproducts is a form of recycling. Logging byproducts with commercial markets include chips, shavings, excelsior, sawdust, bark, and pine straw (Thomas and Schumann 1993). Sawmill slabs and edging strips from rough-cut products are an important source of wood for charcoal in Missouri, where many manufacturers operate small kilns or retorts. Other products from wood byproducts include animal bedding and litter products, soil conditioners and mulches, particleboard, and fireplace logs.

Indicator 34. Supply and consumption/use of nonwood products

Nonwood forest products include maple syrup, wild berries and fruit, charcoal, decorative wood, botanicals and pharmaceuticals, greenery, weaving and dying materials, and many other items. A variety of profitable products are being discovered that come from lichens, fungi, algae, and microorganisms.

The supply and consumption of nonwood products, like conventional wood products, is dependent on biological, social, and economic factors. Vegetative management practices can directly affect the supply of desired products. Landowner preferences can affect access to products, and closure of one gathering area tends to increase pressure in another. In addition, cultivation of a special product can eliminate the need for individual collection (Emery 1999).

A standardized system for collecting or compiling nonwood forest products supply and consumption information is not yet available. Indicator 30, value and quantities of production of nonwood forest products, lists examples of commercial development in this area. Currently reported values are conservative, and data on only a fraction of the nonwood resources harvested from public and private lands are collected systematically.

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.

Indicator 35. Area and percent of forest land managed for general recreation and tourism, in relation to the total area of forest land

The Northern United States had an estimated 144 million acres of forest 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 is in private ownership (63 percent). The remainder is administered by Federal agencies (9 percent), State and local governments (19 percent), and industrial landowners (8 percent) (Cordell and Betz 2003, Smith and others 2001).

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 or friends. Most public forest lands are available to all. On the other hand, only a portion of private lands are available for recreation. 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 highest percentage of private nonindustrial land open to the general public for recreation (13 percent) (Cordell and Betz 2003, Cordell and others 1990). In New York, a survey of industrial forest companies indicated that about 75 percent of company land was leased for recreation purposes, generally hunting (Capozzi and Dawson 2001).

Throughout the Eastern United States, State and local governments manage over 30 million acres of recreation lands. Nationally, State-designated rivers significant for recreation, historical, scenic, or wildlife reasons number 60,000 miles, of which over 70 percent are in the East. County and municipal lands are available for recreation purposes and are generally intensely developed and highly accessible (Cordell and others 1990).

The USDA Natural Resources Conservation Service estimates of total forest land indicate that the amount of forest land acreage has steadily increased since 1982 (figure 6.7, appendix 6–G) (USDA NRCS 2000), but is leveling out and is expected to decrease in the future, which will affect the amount of land available for recreation.

Indicator 36. Number and type of facilities available for general recreation and tourism, in relation to population and forest area

A combination of public and private facilities exists in the Northern United States, although a complete inventory is not available. National forests in the Northern United States host 428 developed recreation areas. This is about one recreation area for every 10 square miles of national forest, a ratio of 56,500 Northern United States residents per national forest recreation area.

Information on State, local, and private recreation facilities is difficult to come by, but some studies are being conducted. For example, an inventory of campgrounds in the Lake States of Michigan, Wisconsin, and Minnesota found that 1,854 campgrounds hosted 147,585 campsites (Leefers and Vasievich 1999). Using 1990 census figures (USDC Bureau of the Census 2002), this computes to a ratio of 10,000 Lake States residents per campground, or 125 residents per campsite. Roughly 56 percent of the campgrounds and nearly two-thirds of the campsites were privately owned; 9 percent of the campgrounds and 3 percent of the campsites are located in national forests. State recreation areas in general had the most campsites per campground (133); State and national forests had the least (26 and 27, respectively).

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 people engage in during an outing (table 6.9). 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.

The implication for the Northern United States is that trails and green space, especially those located near large population centers, will be used more heavily, and the closure of recreation opportunities on private lands will have to be addressed through cooperative public and private efforts. Private rural lands open for recreation, other than industry-owned parcels, are declining owing to conversion to other uses and to increased closures

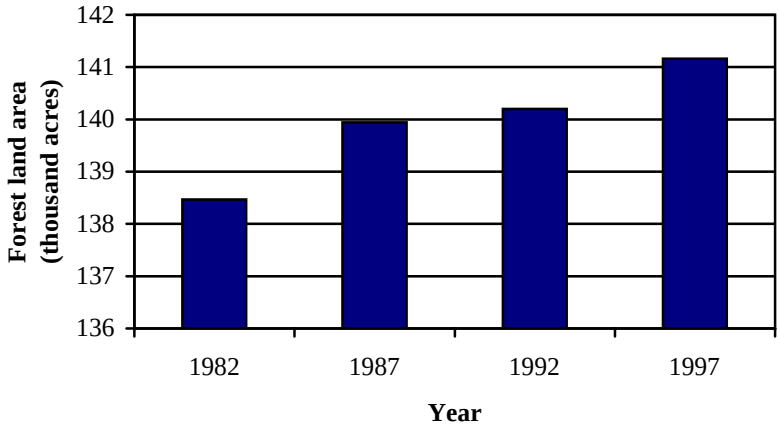

Figure 6.7. **Area of forest land[1] in the Northern United States, 1982–1997** (USDA NRCS 2000).

[1]Forest land in this case is a land cover/land use category that is at least 10 percent stocked by single-stemmed woody species of any size that will be at least 4 meters (13 feet) tall at maturity. Also included is land bearing evidence of natural regeneration of tree cover (cutover forest or abandoned farmland) and not currently developed for nonforest use.

or more restrictive access policies. Private landowners are often hesitant to provide access to their land for public use without economic incentives or protection of the uses for which they own the land.

Management, resource availability, access, and facility needs are likely to be most acute in the East, where effective recreation opportunities are least, crowding is the greatest, and private land closures have the most impact on recreation opportunities. To meet increasing demand for outdoor recreation in the Northern United States, increasing public access to both public and private lands will be necessary. More land exchanges, easements, acquisitions, and partnerships may be needed to provide this access (Cordell and others 1990).

Table 6.9. **Recreation activity days occurring in forest settings in the Northern United States, 2000–2001** (adapted from Cordell and Betz 2003).

Activity	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

There were 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 under Federal jurisdiction in 1987 (Cordell and others 1990).

Indicator 37. Number of visitor days attributed to recreation and tourism, in relation to population and forest area

Approximately 41 percent of the U.S. population resides in the Northern United States. In 1987, there were approximately 98.7 million recreation users in the region, defined as those at least 12 years old participating in a recreational activity. Over 77 million visitors a year enjoy recreating in national forests in the Northern United States. Annual recreation use has remained fairly stable over the last decade in relation to population growth, at about 4 visitor days per person or 9 visits per person (Cordell and others 1990).

Most visitors to State parks and recreation areas are day users who travel 25 to 35 miles one way and stay an average of 3 to 4 hours. English and others (1993) suggested that northeasterners would drive 75 to 100 miles to visit back-country sites and remote lakes and streams. Intensively developed winter activities could require a driving distance of as much as 250 miles.

Investment in the Forest Sector

Indicator 38. Value of investment, including investment in forest growing, forest health and management, planted forests, wood processing, recreation, and tourism

Nurseries

In the Northern United States, State governments produce over half of the seedlings used in reforestation projects. The remaining stock is grown by industry, and, to a lesser extent, by local and Federal government entities. In 1998–1999, public and private nurseries produced 138 million trees (USDA Forest Service 1999c) (figure 6.8, appendix 6–H). The market value of this level of seedling production is approximately $27 million.

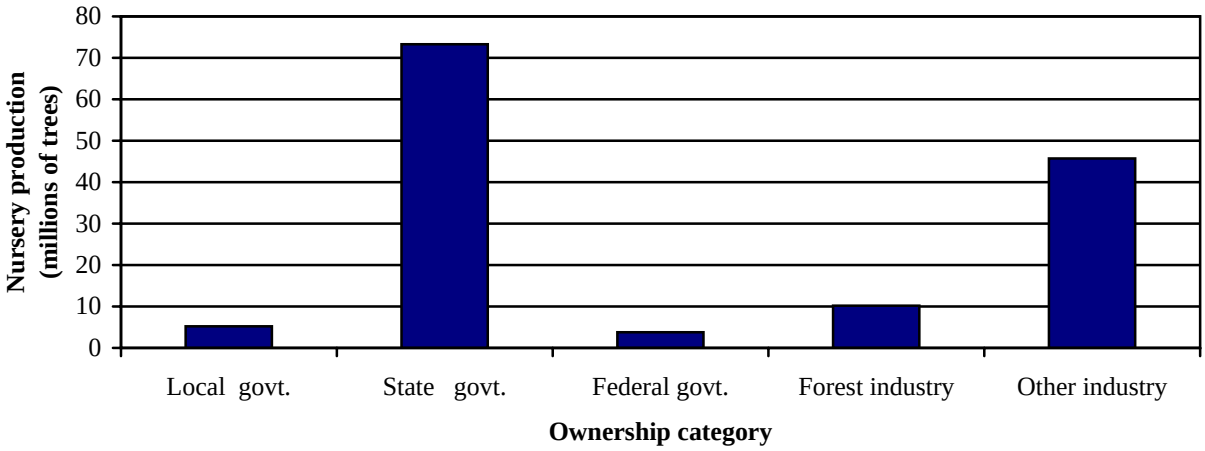

Figure 6.8. **Nursery production in the Northern United States by ownership category (October 1, 1998, through September 30, 1999)** (USDA Forest Service 1999c).

Planted Forests

On forest lands in the Northern United States, approximately 95 to 99 percent of the regeneration is accomplished through natural regeneration methods in association with harvesting. The remaining 1 to 5 percent is accomplished by tree planting on abandoned fields and pasturelands. In the 1998–1999 growing season, nearly 70,000 acres were reforested (USDA Forest Service 1999c) (appendix 6–I). This represents an investment of $22.5 million. Although planting costs differ among States because of species selection and site conditions, the average cost for the Northern United States is $322 per acre.

Forest Management and Improvement

Forest management and improvement is done for a number of purposes, including timber stand improvement, wildlife enhancement, watershed protection, fire prevention, insect and disease prevention, and protection from destructive grazing. In 1998–1999, 835,407 acres were treated for one or more of these purposes (USDA Forest Service 1999c) (table 6.10). The total investment value for forest management and improvement is $12.7 million. Because 35 percent of the landowners implementing these practices are retired and plan to remain on site, these practices will benefit future generations.

Table 6.10. **Investment in forest growth and improvement in the Northern United States, 1998–1999** (USDA Forest Service 1999c).

Treatments	Acres	Cost per acre	Investment
		-----Dollars-----	
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**

Forest Health Management and Monitoring

Healthy, productive forest ecosystems are maintained in the Northern United States through Federal, State, tribal, and private partnerships. Efforts include prevention, detection, monitoring, and suppression of damaging insects and disease. In addition, technology transfer is achieved through the development of training materials and reports on specific insect and disease problems. The Federal investment in forest health management and monitoring for the Northern United States was $10.2 million in 1999 and rose to $15 million in 2000. This increase reflects a change in pest suppression needs, specifically the southern and western advancement of the gypsy moth.

Wood Processing

In the past three decades, industry investment has increased for the paper and allied products sector at a higher rate than for the lumber and wood products sector. In 1994, investments in new capital expenditures and pollution abatement and control in the Northern United States were estimated at $6.5 billion (AF&PA 1999). These measures of gross investment, although not providing a complete picture of investment, indicate an expanding paper sector and a relatively stable lumber and wood products sector, as well as continuous improvement in pollution abatement and control (appendix 6–J).

Recreation and Tourism

Regionwide data are available in such a form that investment in forest-related recreation and tourism could not be separated. State estimates include amusement, theater, hotel receipts, and other metropolitan totals; therefore, an estimate has not been attempted here.

Indicator 39. Level of expenditure on research and development, and education

Research and Development

Funding for research by the USDA Forest Service began a downward trend in the 1980s. In 1999, a USDA investment of approximately $40 million was directed toward research for forests and forest products in the Northern United States. This represented about a 20-percent decrease over the previous 5 years, while funding levels for other institutions increased slightly. About half of the total USDA forestry research funding is allocated for cooperative Federal and State grant programs.

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 6.9). Fifty-two percent of this funding was provided by State governments and nearly one-third by Federal government sources. Almost half of the Federal support ($10.9 million) was through the USDA Cooperative State Research Extension and Education Service (CSREES). A principal component of the USDA cooperative programs is the McIntire-Stennis Cooperative Forestry Research Program, which provides roughly 10 percent of university forestry funding. The 25 universities eligible for this program in the Northern United States received over $7.3 million in McIntire-Stennis funds in 1999 and 2000 (appendix 6–K). Other Federal sources of funding include the Act of 1887 Establishing Agricultural Experiment Stations Act (Hatch Act) funds for State agriculture experiment stations and forestry school research, and the Renewable Resources Extension Act of 1978 grants.

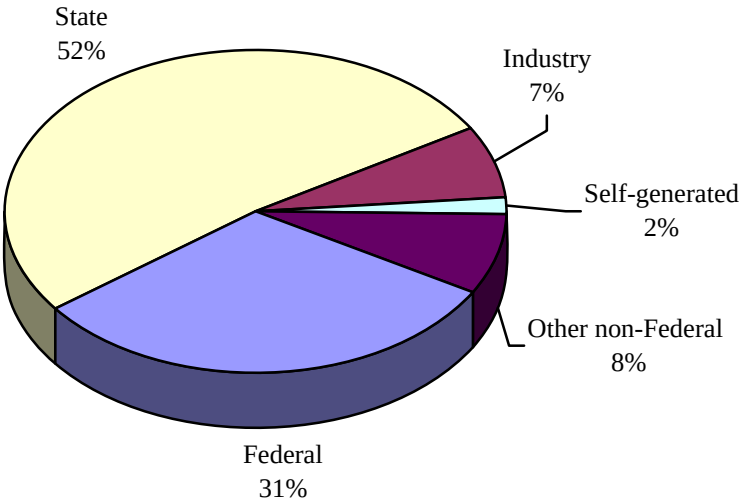

Figure 6.9. **National investment in forestry schools, 2000**. Of the $76.4 million invested in forestry schools in 2000, the largest portion came from State governments (Norland 2003).

Education

The USDA Forest Service is currently providing Northern States with an annual allocation of $10,000 to $15,000 each for conservation education. This money funds financial and technical assistance to State agencies and other organizations providing natural resource-based education. The target audiences are urban dwellers, youth, and national forest visitors. Topics include the following:

- Sustainability of natural and cultural resources in forest, grassland, and aquatic ecosystems

- Developing awareness and understanding of the interrelationships in natural systems and between people and the land
- The value of trees, forests, and forest ecosystems in enhancing our quality of life
- Caring for trees, forests, and forest ecosystems to ensure forest health and sustainability
- Maintaining and restoring the biodiversity of native forest ecosystems
- The positive role trees, forests, and forest ecosystems play in protecting water quality

The private sector is also contributing to this effort. Project Learning Tree (PLT), a program of the American Forest Foundation—a private nonprofit organization—provides environmental education curriculum materials and professional development opportunities to educators of children from preschool through 12th grade. The activities within the curriculum materials focus on:

- Developing students' awareness of their environment
- Building on their knowledge of natural resources as well as the environment
- Challenging what students have learned
- Encouraging students to take responsible action regarding environmental issues

Many of the PLT activities address forest-related topics, from learning the different parts of a tree to developing a management plan for a 400-acre forest.

Indicator 40. Extension and use of new and improved technology

Many advances in wood utilization technology occurred during the 20th century. The focus at the beginning of the 1900s was clear wood for solid wood products and wood preservation as a major element in efficient utilization of wood. However, major investments have been made in the development of composite wood products. This development was spurred in part by a reduction in the size of available raw materials; the use of second- and third-growth timber, which is less stable and more prone to warping; and advances in adhesive technology, mechanics, and industrial processes.

Wood composites, including particleboard, hardboard, oriented strand board (OSB), structural composite lumber, structural plastics, cement-wood combinations, and the efficient combination of wood and steel, are standardized under the grouping glued laminated timber. Other structural composite products include laminated veneer lumber, parallel strand lumber, and oriented strand lumber. The most significant nonstructural engineered wood products are particleboard and medium density fiberboard (MDF). Particleboard, a wood panel product consisting of wood particles of various sizes that are bonded together with a synthetic resin or binder under heat and pressure, is used widely in the manufacture of furniture and cabinets, in floor underlayment in home construction, and in many other applications.

The first composite wood products were developed in the 1930s to use smaller, lower quality, and "undesirable" trees. Composites began with plywood, a product that consists of veneers arranged in perpendicular layers. Rising plywood prices encouraged substitution of OSB and other composite products in residential and commercial building. Oriented strand board consists of wood strands bonded with adhesives to form a mat. Its popularity is reflected in the great number of new OSB mills being built, and in the plant expansions of several current

major OSB producers. In 1995, the wholesale value of OSB production surpassed $3 billion, an increase of 50 percent over the previous 10 years.

Investments in composite research and standardization challenges will continue because of heightened environmental concerns and the concomitant challenges of new formulations.

Indicator 41. Rates of return on investment

Examining rates of return on investment provides a means of comparing forestry investment returns with other sectors of the economy. The rate of return has increased overall in the North, indicating increased utilization of forest assets (table 6.11). This rate of return reflects a fairly moderate rate of production and indicates that forest assets in the Northern States are not being over-exploited from an overall timber perspective. This rate of return does not, however, take into consideration the possible exploitation of certain desirable species for which regeneration failure is common.

Table 6.11. **Rates of return on investment[1] in the Northern United States** (USDA Forest Service 1997a).

Year	Total asset value of standing forests	Total net revenue from timber production	Rate of return index (net revenue/asset value)
	----Thousand dollars----		Percent
1962	77,803	1,231	1.58
1977	98,060	1,220	1.24
1987	108,512	2,718	2.50
1992	120,646	2,746	2.28

[1]All amounts have been adjusted to reflect value in 1987.

Cultural, Social, and Spiritual Needs and Values

The practice of protecting outstanding natural areas for their scenic beauty and for recreation and enjoyment by the public began in the United States with the first “national park,” Yellowstone, proclaimed in 1872. The idea of protecting entire ecosystems to preserve biological diversity developed later. **Biosphere reserves** are sites of exceptional richness with respect to the diversity and integrity of biotic communities of plants and animals within natural ecosystems. The primary use of biosphere reserves is for research, education, and training. **World heritage sites** are unique natural and cultural sites considered to be of outstanding universal significance. Wilderness areas protect a pristine natural environment from contemporary human activity so that natural processes dominate (Martin 1992).

The forests that evoke the most reaction from the citizenry are old-growth forests. Old-growth forests offer visitors a spirituality of sorts, a tie to the past, and create a sense of awe. Encounters with old-growth forests give greater depth and understanding to scientific explorations, and psychological, poetic, and spiritual expression.

Although most religions do not overtly include nature as a part of spiritual growth, Native American culture has been seen as that of living in harmony with nature. 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 ancient forests. For the purposes of indicator 42, forests that provide cultural, social, and spiritual needs and values are considered to have attributes that people want to preserve, such as wilderness, parks, or forested areas being protected by nonprofit groups.

Indicator 42. 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

Forest land is set aside in each State in the Northern United States for the protection of cultural, social, and spiritual needs and values. In addition to Federal land (figure 6.10, appendix 6–L), there are State and county parks, natural areas, and historic sites. Private land rights can also be held by government or private land trusts through conservation easements. Through August 31, 2000, under the USDA Forest Service Forest Legacy Program, 97,308 acres in 10 of the Northern United States have been purchased or placed under conservation easement (appendix 6–M). The value of these transactions is roughly $40,784,000, including donations, State purchases, and Federal payment of $20,433,000 (USDA Forest Service 2000b).

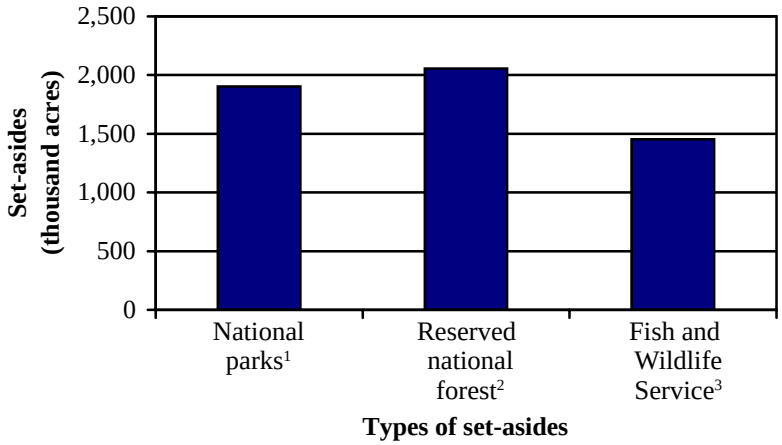

Figure 6.10. **Federal set-asides**. Over 5.4 million acres of Federal land had been withdrawn from commercial activity as of 2000 (AF&PA 2001).

[1]Includes national parks, battlefields, seashore and recreation areas, historic sites and other designations within the National Park System. Non-Federal public and private lands managed by the National Park Service are also included.
[2]Includes national wildlife refuges, wilderness areas, national wildlife waterfowl production areas, coordination areas, fish hatcheries, migratory waterfowl refuges, and administrative sites.
[3]Specially designated areas of the National Forest System include wilderness areas, wild and scenic river areas, primitive areas, scenic and scenic-research areas, recreation areas, game refuges and wildlife preserve areas, monument areas, volcanic monument areas, and historic areas.

Indicator 43. Nonconsumptive use forest values

Some values associated with forests are neither economic nor production oriented. In fact, everyone who benefits from America's rural and urban forests assigns a unique value to these resources. Use level is an appropriate measure of nonconsumptive forest values. Although no complete data source exists, various studies give an indication of the benefits derived.

For example, at Boston's Arnold Arboretum during summer 1992, 3,983 individuals engaged in 98 different activities on 25 sample days. The highest use levels were recorded on sunny afternoons, particularly on weekends. Activities included strolling, conversing,

looking at something, cycling, bird watching, reading, getting exercise, enjoying the beauty of the area, or simply sitting in the grass. The incidence of problem behavior was slight. These activities represent the personal benefits produced by the arboretum in that they accrue to the individuals involved. In addition, parks provide biological benefits—they modify microclimates, reduce air pollution, and absorb runoff of surface water (More and Blackwell 1998).

Water- and land-based recreation activities in America (camping, hiking, rafting, biking, nature study, photography, picnicking, swimming, wildlife observation, visiting prehistoric sites, and relaxing) have a net economic value ranging from $15 to $155 per person, per day. Most of these activities range in value from $20 to $30 per person, per day (USDA Forest Service 1997a).

Employment and Community Needs

Indicator 44. Direct and indirect employment in the forest sector and the forest sector employment as a proportion of total employment

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 over 613,000 people in 1997 (table 6.12).

Table 6.12. **Employment, payroll, and hourly wages for major wood processing industries in the Northern United States, 1997** (USDC Bureau of the Census 2002).

Industry	Number of employees	Annual payroll	Average wages per hour for production workers
		Thousand dollars	Dollars
Logging	13,628	286,254	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	**613,678**	**19,215,101**	—

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 industries (over twice as much as the lumber industries) reflects the need for more training, mill ownership, degree of unionization of the labor force, and relatively stable levels of end product consumption.

Indicator 45. Average wage rates and injury rates in major employment categories within the forest sector

Average Wage Rates in Forestry, Agriculture, Fishing, and Related Fields

Nearly a third of the Nation's workers in agriculture, forestry, fishing, and related fields were employed in the Northern United States in 1998. The highest paid categories of workers in forestry occupations are foresters and conservation scientists, forest fire inspectors, and fire prevention specialists. There are considerable disparities in wage rates for similar jobs from State to State (appendix 6–N). For example, in 1998, the median rate for logging tractor operators among States ranged from $8 to $12 per hour, the rate for forest and conservation workers ranged from $7 to $16, and the rate for fallers and buckers ranged from $7 to $13. Mean annual salaries for supervisors and managers in agriculture, forestry, fishing, and related fields varied as much as $10,000 among the 20 Northern States. Wages in the Northern United States were slightly higher than the national average.

Most Federal and State forestry positions are technical, professional, and managerial. State forestry technicians are paid the least and managers the most (figure 6.11). A maxim in forestry is that work gets done in the field. The average annual difference in pay between entry level and experienced field or service foresters among the 20 States is $11,136 (without considering cost-of-living adjustments). Among States, the premium for remaining actively engaged in field or service forestry for the course of a career ranges from $5,000 to $23,800 per year with a median value of $10,000 (appendix 6–O).

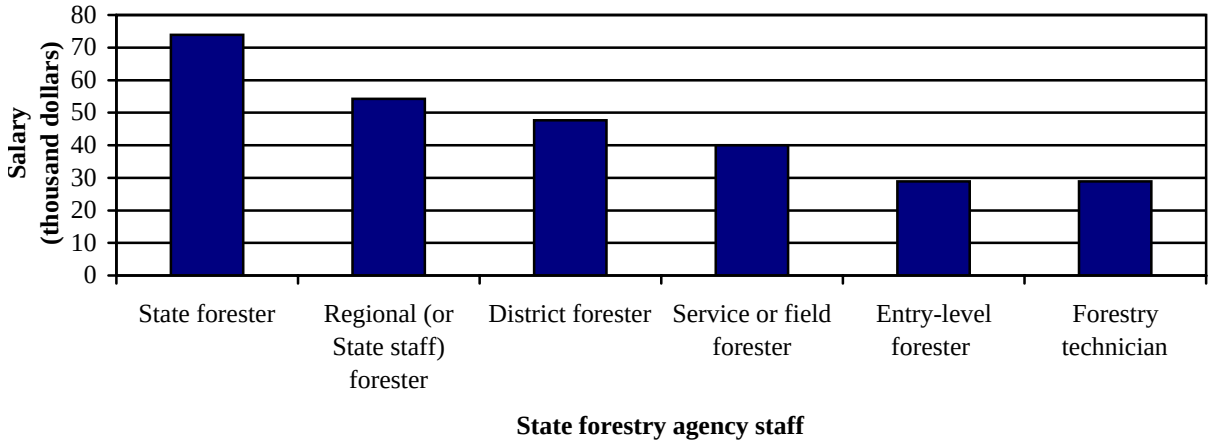

Figure 6.11. **Average annual salary for State forestry agency staff in the Northern United States, fiscal year 1998** (National Association of State Foresters 1998).

Federal employees are paid according to a general schedule of wages (GS) set according to grade (table 6.13). Professional and administrative employees are hired at the GS–5 level and move quickly to GS–9 and over time to GS–11. Technicians are usually hired at GS–4 and can advance to GS–7. District Ranger, program manager, and regional technical specialist positions are GS–12 or 13. The Forest Supervisor of a national forest is a GS–14 or 15. Wages increase within grades for experience gained with years of service up to nine times in 20 years of service. Senior executives and nonresource-based technical positions (such as electrician and mechanic) have different pay schedules.

Average Injury Rates in Forestry and Related Fields

A complete picture of the hazards to the forest resource management community would require data, currently unavailable, on injury rates for such areas as forest-based recreation management and nontimber commodity production, as well as for forest harvest and products jobs.

Table 6.13. **General schedule of wages for Federal professional, technical, and administrative employees, 1998** (USDA Forest Service 1998a).

General schedule grade	Starting salary	Within-grade increase amounts
	-----Dollars-----	
4	17,848	595
5	19,969	666
6	22,258	742
7	24,734	824
8	27,393	913
9	30,257	1,009
10	33,320	1,111
11	36,609	1,220
12	43,876	1,463
13	52,176	1,739
14	61,656	2,055
15	72,525	2,418

Many forest products jobs have gotten steadily safer in the last decade, although logging continues to be one of the most dangerous of professions. Injury and death are frequently associated with jobs such as felling, limbing, bucking, and choke setting. Other high-risk forestry occupations are truck driver, general laborer, and material machine operator. Between 1980 and 1989, an estimated 1,492 deaths occurred in the logging industry, with an average annual fatality rate of 164 deaths per 100,000 workers (U.S. Department of Health and Human Services 1995). The fatality rate fell to roughly 128 deaths per 100,000 workers between 1992 and 1996, although, with over 772 fatalities, it was still the second most dangerous occupation (behind fishing) for U.S. workers (USDL Bureau of Labor Statistics 1998a, 1998c). The fatality rate for black workers was slightly higher than for white and other minority workers. In addition to fatalities for this period, over 30 percent of logging injury cases resulted in 31 or more lost workdays. Although the total number of lost workday cases dropped from 4,537 in 1992 to 2,136 in 1996, there is still room for improvement.

In the Northern United States, 172 loggers are known to have died between 1992 and 1996. Injury rates for occupations in key forest sectors in the Northern United States (table 6.14, appendix 6–P) are higher than the national average. In 1998, there were an estimated 27,000 injuries in the Northern United States (excluding New Hampshire, Ohio, and Pennsylvania), for occupations including agriculture, forestry, and fishing. In the Northern United States, the rate of injury appears highest for the lumber and wood products industry.

Indicator 46. Viability and adaptability to changing economic conditions of forest dependent communities, including indigenous communities

The Northern United States, like other regions of the country, has been affected by recent adjustments in the forest sector. In this region, timber industry jobs are declining in spite of increased logging because mechanization is enabling more work to be done by fewer people, competition is shifting jobs to other regions of the world, and improvements in

Table 6.14. **Comparison of national incidence rates (cases per 100 full-time employees) of nonfatal occupational injuries and illnesses, and lost workdays due to injury by industry in the Northern United States, 1998** (USDL Bureau of Labor Statistics 1998a, 1998c).

Industry	1998 average annual employment		Incidence rate due to injury and illness combined		Incidence rate due to injury alone		Incidence rate of injuries resulting in lost workday(s)		Number of Northern States reporting
	North	National	North	National	North	National	North	National	
	---Thousands---								
Agriculture, forestry, and fishing	333.4	1,815.0	8.1	7.9	7.9	7.6	3.6	3.8	17
Lumber and wood products	171.8	816.0	14.4	13.2	13.7	12.6	7.4	6.5	14
Paper and allied products	202.6	678.6	8.9	7.1	8.3	6.6	4.6	3.6	13

[1]Data for individual States is listed in appendix 6–P.

engineering and technology have reduced society's reliance on wood manufacturing. In the "Northern Forest" communities of rural New York, Vermont, New Hampshire, and Maine, an increasingly global business environment has fueled the closure of several large paper mills and the sale of millions of acres of forest. Recreation, tourism, and service-sector jobs have replaced those in the mills and in the woods (National Wildlife Federation 1996).

Since employment in rural areas has been relatively more dependent on goods than on service sectors, they have experienced deeper recessions and slower recoveries in ongoing structural transformations. Whereas some communities have shown resilience in locating alternative sources of income, others still face economic hardship. Several organizations have formed to help communities respond to change and to carve out a better future for residents, including the Northeast Natural Resource Center; the North East Forest Association; the Great Lakes Forest Alliance; the Great Lakes Indian, Fish, and Wildlife Commission; and State and local rural development councils. Although their goals differ, these groups generally embrace an inclusive approach, bringing together business, government, and cultural leaders who assess investment and divestment opportunities at multiple levels and guide the community in achieving a balance of extractive and nonextractive land uses. Successful transformations can be characterized by finding a common purpose, enabling private-public partnerships, customizing solutions to meet local situations, and learning and adapting along the way.

Massachusetts' Quabbin Reservoir Watershed, a primary source of clean water for metropolitan Boston, is an example of how ecologically sound practices and a healthy forest products sector can sustainably develop together. Within the framework of a long-term management plan, wildlife is protected (including the first bald eagle to hatch in Massachusetts in 90 years, in 1989), recreation is enhanced, and a small but steady volume of sawlogs, firewood, and chipwood is sold almost entirely to a few dozen local contractors. These contractors in turn feed a value-adding regional production chain. The community and economic benefits include employment, equipment expenditures, wood product sales and processing, recreational expenditures, stable or increasing property values, and an attractive backdrop for tourism (National Wildlife Federation 1998).

Indicator 47. Area and percent of forest land used for subsistence purposes

Subsistence activities include those activities carried out on forest land by individuals or families to provide goods for personal consumption or gifts. Such activities do not require conversion of the forest resource and include hunting, gathering, timbering, and firewood extraction. No source for meaningful data on the area and percentage of forest land used for subsistence purposes is known. All forest land, however, potentially could be used for subsistence purposes.

Summary and Conclusions

Forest land acreage increased over the last half of the 20th century but is leveling off while population increases will continue. This combination of factors 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. Standing wood inventories in the Northern United States also increased over the last half of the 20th century and are projected to decrease in the new millennium owing to increased demand for wood products. Forest products supply and consumption steadily increased between 1960 and 1990. In the Northern United States, all categories—roundwood, sawnwood, wood-based panels, wood pulp, and paper and paperboard—have shown a marked increase in supply and total consumption. The U.S. per capita consumption of all products has increased. The demand for paper recycling is higher in the Northern United States than it is nationwide, but the recycled fiber resource is highly underutilized.

Wood products and recreation are the two largest forest-based economic sectors in the Northern United States. Timber-processing industries include lumber, paper manufacturing, and furniture. Public land is an important asset for the recreation-based economy as private landowners are becoming more hesitant to open their land without economic incentives or protection from misuse of their land. Opportunities for wilderness and backcountry recreation are decreasing while developed recreation sites are increasing. Outdoor recreation sites closest to urban centers get the most use. Nonwood products such as maple syrup, botanicals, oils, mushrooms, berries, cones, and seeds provide an important source of income in some locales. The collection and production of nonwood products is often strongly interwoven into the social and cultural traditions of communities.

Public investments include tree nurseries, tree planting, forest management, forest inventory and forest health monitoring, public education, and research. The rate of return on investments in timber production increased from 1970 to 2000. The need for investments in forest health and in insect and disease control is increasing because of exotic and invasive species introductions. Industry investment has increased at a higher rate for paper and allied products than for lumber and wood products. Diverse composite products have been developed to use smaller trees and trees with more defects. Public and private investments in research appear to fall short of those needed.

The timber-processing industry contributes a greater percentage of overall income and employment in the Northern United States than in other parts of the country. Paper manufacturers provide relatively higher compensation to employees than do lumber or furniture manufacturers. Compensation for forestry workers varies highly from State to State.

Professionals, managers, and scientists receive the highest wages. Foresters generally have limited financial incentives to continue in field or service forestry for the course of their careers. Forest product jobs have gotten steadily safer, but the death and injury rates are still higher than for most other professions. Mechanization, globalization, and new technology have resulted in a decline of timber industry jobs. This impacts rural areas most dramatically, often causing a shift to a less lucrative tourism or service-based economy.

Appendix 6–A. Volume of roundwood products, logging residues, and other removals from growing stock and other sources in the Northern United States, by species group, 1996

Class and source of material	Species group		
	Total	Softwoods	Hardwoods
	Thousand cubic feet		
Roundwood products			
Growing stock	2,418,920	629,380	1,789,541
Other sources	1,090,018	186,495	903,523
Total	3,508,938	815,875	2,693,064
Logging residues			
Growing stock	255,951	30,918	225,033
Other sources	1,103,631	261,618	842,013
Total	1,359,582	292,536	1,067,046
Other removals			
Growing stock	97,545	8,048	89,496
Other sources	103,768	5,966	97,802
Total	201,313	14,014	187,298
All classes			
Growing stock	2,772,417	668,346	2,104,070
Other sources	2,297,417	454,078	1,843,339
Total	5,069,834	1,122,424	3,947,409

Source: Smith and others 2001.

Appendix 6–B. Volume by class of roundwood product from growing stock and other sources in the Northern United States, by species group, 1996

Roundwood products	Species group		
	Total	Softwoods	Hardwoods
	----Million cubic feet----		
Sawlogs			
Growing stock	1,125	282	843
Other sources	154	54	100
Total	1,280	337	943
Veneer logs			
Growing stock	54	3	51
Other sources	7	< 1	6
Total	60	3	57
Pulpwood			
Growing stock	876	305	571
Other sources	188	64	124
Total	1,063	369	695
Composite products			
Growing stock	185	9	176
Other sources	17	2	14
Total	202	12	190
Fuelwood			
Growing stock	130	10	120
Other sources	712	58	654
Total	842	69	773
Posts, poles, and pilings			
Growing stock	14	7	6
Other sources	4	2	1
Total	17	9	7
Miscellaneous products			
Growing stock	36	13	23
Other sources	9	4	4
Total	45	17	28
Total products:			
Northern U.S.			
Growing stock	2,419	629	1,790
Other sources	1,090	186	904
Total	3,509	816	2,693
Subregional contributions			
Northeastern States	1,772	545	1,228
North Central States	1,737	271	1,465

Source: Smith and others 2001.

Appendix 6–C. Economic contribution of logging in the Northern United States, 1997[1]

State[2]	Number of establish-ments	Number of employees	Annual payroll	Production workers' wages	Total value of shipments	Value added
			----------Thousand dollars----------			
Indiana	84	601	14,532	11,276	61,741	35,756
Maine	484	3,203	81,961	54,458	838,692	270,295
Maryland	69	296	5,777	4,373	23,857	14,047
Michigan	404	1,915	40,991	31,180	181,022	105,580
Minnesota	215	946	18,590	14,960	91,643	51,213
Missouri	97	325	5,050	4,017	24,175	13,258
New Hampshire	150	601	13,203	10,323	60,239	36,277
New York	266	962	19,157	15,183	100,861	56,702
Ohio	146	785	18,025	14,331	82,271	45,009
Pennsylvania	341	1,008	17,526	13,441	73,048	41,015
Vermont	103	251	5,147	4,272	22,048	13,419
West Virginia	326	1,395	19,917	16,294	82,006	48,899
Wisconsin	423	1,340	26,378	19,869	146,033	69,856
Total	**3,108**	**13,628**	**286,254**	**213,977**	**1,787,636**	**801,326**

[1]Includes data for industry groups and industries with 100 employees or more.
Manufacturing Industry series number for logging is 113310.
[2]Data not reported for all 20 Northern States.
Source: USDC Bureau of the Census 2002.

Appendix 6–D. Economic contribution of wood product manufacturing in the Northern United States, 1997[1]

State	Number of establish-ments	Number of employees	Annual payroll	Production workers' wages	Total value of shipments	Value added
			----------Thousand dollars----------			
Connecticut	115	1,500	46,141	29,502	191,055	94,418
Delaware	26	809	18,383	15,096	90,248	42,029
Illinois	460	9,614	232,290	158,670	1,138,406	494,510
Indiana	601	21,692	563,481	411,198	3,167,438	1,234,961
Iowa	161	8,298	224,780	161,283	1,063,126	557,861
Maine	255	7,930	189,469	141,625	925,361	392,850
Maryland	150	3,908	91,766	65,406	566,558	203,345
Massachusetts	230	2,874	75,478	47,805	398,248	161,462
Michigan	627	13,729	361,385	246,828	2,033,688	832,427
Minnesota	363	15,356	500,827	360,882	2,499,139	1,053,736
Missouri	586	9,741	196,245	138,750	1,030,082	421,784
New Hampshire	179	3,665	94,691	64,196	476,121	223,423
New Jersey	161	2,793	80,339	46,786	406,402	188,453
New York	575	10,375	250,226	174,942	1,333,633	571,216
Ohio	703	20,133	452,802	342,839	2,385,614	1,111,298
Pennsylvania	997	24,470	577,732	411,107	3,292,725	1,371,048
Rhode Island	47	526	13,398	9,770	101,319	28,558
Vermont	140	3,290	82,220	61,843	419,582	183,510
West Virginia	289	7,752	159,023	126,872	1,074,260	408,856
Wisconsin	683	28,030	680,035	490,103	3,747,972	1,529,500
Total	**7,348**	**196,485**	**4,890,711**	**3,505,503**	**26,340,977**	**11,105,245**

[1]Includes data for industry groups and industries with 100 employees or more.
Manufacturing Industry series number for wood product manufacturing is 321.
Source: USDC Bureau of the Census 2002.

Appendix 6–E. Economic contribution of paper manufacturing in the Northern United States, 1997[1]

State	Number of establish-ments	Number of employees	Annual payroll	Production workers' wages	Total value of shipments	Value added
			----------Thousand dollars----------			
Connecticut	90	6,069	238,369	158,381	1,839,441	1,005,167
Delaware	9	2,717	72,356	48,609	804,382	573,801
Illinois	372	28,968	1,015,158	647,550	5,872,807	2,828,666
Indiana	168	13,311	431,636	277,790	2,765,357	1,206,840
Iowa	44	5,480	183,930	130,708	1,531,237	705,961
Maine	34	13,801	665,786	493,718	4,460,440	2,065,768
Maryland	55	7,553	259,278	176,656	1,166,427	568,882
Massachusetts	233	19,292	711,589	427,301	4,041,584	1,955,643
Michigan	224	19,660	799,099	534,177	4,878,245	2,262,681
Minnesota	130	15,349	619,546	432,812	4,049,622	1,926,768
Missouri	136	12,788	413,822	294,020	2,986,338	1,370,113
New Hampshire	40	3,822	142,190	93,586	882,412	500,593
New Jersey	258	17,095	619,535	384,696	3,210,798	1,511,335
New York	405	27,055	972,164	628,717	5,139,652	2,364,714
Ohio	377	30,227	1,135,895	746,753	6,844,433	3,217,975
Pennsylvania	328	32,228	1,101,410	723,142	8,901,062	4,535,220
Rhode Island	42	1,955	63,417	39,359	302,847	156,638
Vermont	16	1,735	58,952	41,150	382,141	172,017
West Virginia	15	777	23,737	16,264	129,747	61,483
Wisconsin	254	42,828	1,885,193	1,267,300	12,651,514	5,813,159
Total	**3,230**	**302,710**	**11,413,062**	**7,562,689**	**72,840,486**	**34,803,424**

[1]Includes data for industry groups and industries with 100 employees or more.
Manufacturing Industry series number for paper manufacturing is 322.
Source: USDA Bureau of the Census 2002.

Appendix 6–F. Economic contribution of wood furniture manufacturing in the Northern United States, 1997[1]

State	Number of establish-ments	Number of employees	Annual payroll	Production workers' wages	Total value of shipments	Value added
			----------Thousand dollars----------			
Connecticut	175	1,608	50,076	34,039	161,530	95,964
Illinois	519	6,773	181,852	123,844	699,110	376,288
Indiana	334	14,950	379,331	285,958	1,632,513	921,348
Iowa	111	2,734	61,418	50,351	235,601	125,199
Maine	76	449	11,414	6,397	34,477	22,377
Maryland	180	1,850	46,137	30,410	135,633	81,276
Massachusetts	232	2,812	79,793	52,394	279,511	152,307
Michigan	338	6,575	178,034	118,072	727,297	409,917
Minnesota	369	5,828	141,526	101,678	567,261	319,218
Missouri	317	5,354	133,321	100,968	563,559	288,076
New Hampshire	80	1,238	30,784	18,073	93,954	51,074
New Jersey	331	2,990	87,892	60,229	278,689	157,332
New York	709	11,906	315,258	206,435	1,138,393	683,593
Ohio	504	11,365	315,903	200,407	1,740,263	918,631
Pennsylvania	568	12,335	313,285	221,884	1,134,110	650,614
Rhode Island	19	127	2,642	1,809	7,518	4,406
Vermont	39	2,229	52,043	45,569	140,638	71,574
West Virginia	46	768	15,805	10,602	59,179	31,779
Wisconsin	357	8,964	228,560	143,614	917,901	452,946
Total	**5,304**	**100,855**	**2,625,074**	**1,812,733**	**10,547,137**	**5,813,919**

[1]Includes data for industry groups and industries with 100 employees or more.
Wood subsectors of furniture and manufacturing include the following:
- Wood kitchen cabinet and counter top manufacturing (337110)
- Nonupholstered wood household furniture manufacturing (337122)
- Wood television, radio, and sewing machine cabinet manufacturing (337129)
- Wood office furniture manufacturing (337211)
- Custom architectural woodwork and millwork manufacturing (337212)

Source: USDA Bureau of the Census 2002.

Appendix 6–G. Area of forest land in the Northern United States, by State, 1982–1997

State	Forest land[1]			
	1982	1987	1992	1997
	Thousand acres			
Connecticut	1,810.8	1,774.4	1,742.6	1,728.6
Delaware	367.5	360.6	356.3	347.0
Illinois	1,791.5	1,850.7	1,972.9	2,083.5
Indiana	3,526.2	3,537.3	3,512.0	3,631.4
Iowa	3,671.9	3,677.7	3,661.3	3,637.8
Maine	3,028.0	2,944.7	2,835.0	2,657.3
Maryland	2,447.1	2,417.0	2,391.6	2,330.7
Massachusetts	17,688.7	17,679.1	17,679.4	17,633.1
Michigan	15,716.4	15,899.6	15,920.8	16,237.7
Minnesota	14,558.1	14,414.9	14,424.1	14,829.7
Missouri	1,189.3	1,547.5	1,753.6	2,118.3
New Hampshire	4,117.8	4,036.2	3,956.1	3,874.6
New Jersey	1,866.7	1,814.0	1,784.7	1,624.7
New York	16,672.5	17,004.1	17,345.9	17,532.8
Ohio	6,570.6	6,808.9	6,829.0	6,983.5
Pennsylvania	15,440.4	15,519.1	15,478.5	15,306.1
Rhode Island	398.0	393.1	383.8	381.2
Vermont	4,098.9	4,152.5	4,138.8	4,118.0
West Virginia	13,498.4	13,548.1	13,519.4	13,634.1
Wisconsin	10,010.4	10,556.6	10,515.4	10,472.1
Total	**138,469.2**	**139,936.1**	**140,201.2**	**141,162.2**

[1]Forest land in this case is a land cover/land use category that is at least 10 percent stocked by single-stemmed woody species of any size that will be at least 4 meters (13 feet) tall at maturity. Also included is land bearing evidence of natural regeneration of tree cover (cutover forest or abandoned farmland) and not currently developed for nonforest use.
Source: USDA NRCS 2000.

Appendix 6–H. Nursery production in the Northern United States by State and ownership category (October 1, 1998, through September 30, 1999)

State	Federal	State govt.	Local govt.	Forest industry	Other industry	Total
			Thousand trees			
Connecticut	—	500	—	—	—	500
Delaware	—	—	—	—	—	0
Illinois	—	3,640	—	—	—	3,640
Indiana	—	5,250	—	—	150	5,400
Iowa	—	5,600	—	—	1,500	7,100
Maine	—	—	—	—	—	0
Maryland	—	4,257	—	—	—	4,257
Massachusetts	—	—	—	—	—	0
Michigan	3,798	6,000	—	5,000	13,000	27,798
Minnesota	—	13,000	1,500	3,000	9,000	26,500
Missouri	—	4,074	400	—	99	4,573
New Hampshire	—	250	—	—	—	250
New Jersey	—	406	—	—	1,170	1,576
New York	—	1,477	—	—	—	1,477
Ohio	—	5,058	—	—	—	5,058
Pennsylvania	—	2,500	3,318	—	16,000	21,818
Rhode Island	—	—	—	—	—	0
Vermont	—	—	—	—	—	0
West Virginia	—	19,630	—	2,200	4,000	25,830
Wisconsin	—	1,657	—	—	800	2,457
Total	**3,798**	**73,299**	**5,218**	**10,200**	**45,719**	**138,234**

Source: USDA Forest Service 1999c.

Appendix 6–I. Area planted with trees by State in the Northern United States, 1998–1999

State	Area
	Acres
Connecticut	90
Delaware	22
Illinois	7,522
Indiana	13,126
Iowa	3,631
Maine	3,355
Maryland	1,013
Massachusetts	—
Michigan	8,965
Minnesota	8,698
Missouri	1,450
New Hampshire	436
New Jersey	480
New York	352
Ohio	1,517
Pennsylvania	1,013
Rhode Island	—
Vermont	—
West Virginia	17,916
Wisconsin	61
Total	**69,647**

Source: USDA Forest Service 1999c.

Appendix 6–J. Investment in forest industries by State in the Northern United States

State	New capital expenditures	Pollution abatement and control	Operation costs—pollution abatement
		Million dollars	
Connecticut	32.0	9	6.0
Delaware	13.6	N/A	N/A
Illinois	342.0	4	10.0
Indiana	230.0	5	37.0
Iowa	197.0	6	21.0
Maine	113.0	N/A	18.0
Maryland	151.0	4	N/A
Massachusetts	416.0	32	88.0
Michigan	293.0	14	70.0
Minnesota	392.0	N/A	59.0
Missouri	192.0	N/A	52.0
New Hampshire	55.0	26	17.0
New Jersey	138.0	2	35.0
New York	820.0	8	46.0
Ohio	303.0	11	65.0
Pennsylvania	344.0	24	134.0
Rhode Island	2.8	N/A	1.4
Vermont	23.0	N/A	N/A
West Virginia	771.0	40	767.0
Wisconsin	84.0	N/A	N/A
Total	**4,912.4**	**185**	**1,426.4**

Note: N/A = data not available
Source: AF&PA 1999.

Appendix 6–K. McIntire-Stennis funding for eligible State institutions and institutional units in the Northern United States for fiscal years 1998 through 2000

State	Location	Recipient	1998	1999[1]	2000[1]
			----------Dollars---------		
Connecticut	New Haven	Connecticut Ag. Exp. Station	160,438	171,669	171,669
Connecticut	Storrs	Storrs Ag. Exp. Station, Univ. of CT	53,479	57,223	57,223
Delaware	Newark	Ag. Exp. Station, Univ. of Delaware	74,909	80,153	80,153
Illinois	Carbondale	So. Illinois University	157,504	168,529	168,529
Illinois	Urbana	Univ. of Illinois	157,504	168,529	168,529
Indiana	Lafayette	Purdue University	340,283	364,103	364,103
Iowa	Ames	Ag. Exp. Station, Iowa State Univ.	239,188	255,931	255,931
Maine	Orono	Univ. of Maine	542,472	580,445	580,445
Maryland	College Park	Univ. of Maryland	226,551	242,410	242,410
Massachusetts	Amherst	Univ. of Massachusetts	251,825	269,453	269,453
Michigan	East Lansing	Michigan State Univ.	189,248	202,495	202,495
Michigan	Houghton	MI Technological Univ.	189,248	202,495	202,495
Michigan	Ann Arbor	Univ. of Michigan	189,248	202,495	202,495
Minnesota	St. Paul	Univ. of Minnesota	491,925	526,360	526,360
Missouri	Columbia	Univ. of Missouri, School of Forestry	403,467	431,710	431,710
New Hampshire	Durham	Univ. of New Hampshire	302,372	323,538	323,538
New Jersey	New Brunswick	Ag. Exp. Station, Rutgers State Univ.	201,277	215,366	215,366
New York	Ithaca	NY State College, Cornell Univ.	157,732	168,773	168,773
New York	Syracuse	State Univ. of NY, Environmental Science and Forestry	473,197	506,321	506,321
Ohio	Wooster	Ohio Ag. Research and Dev. Center	365,556	391,145	391,145
Pennsylvania	University Park	Ag. Exp. Station, Penn. State Univ.	479,288	512,838	512,838
Rhode Island	Kingston	Univ. of Rhode Island	62,272	66,631	66,631
Vermont	Burlington	Univ. of Vermont	327,646	350,581	350,581
Wisconsin	Madison	Ag. Exp. Station, Univ. of Wisconsin	466,650	499,316	499,316
West Virginia	Morgantown	West Virginia Univ.	378,192	404,665	404,665
Total			**6,881,471**	**7,363,174**	**7,363,174**

[1]Fiscal year 1999 and 2000 values were calculated by using a 7-percent increase over the 1998 budget.
Source: Biles 2000.

Appendix 6–L. Federal set-asides, 2000

State	National parks[1]	Reserved national forest[2]	Fish and Wildlife Service[3]	Total
		Thousand acres		
Connecticut	7.7	—	0.8	8.5
Delaware	—	—	27.3	27.3
Illinois	2.0	—	102.0	104.0
Indiana	—	26.0	138.0	164.0
Iowa	15.0	13.0	10.0	38.0
Maine	58.5	—	13.2	71.7
Maryland	70.0	—	43.0	113.0
Massachusetts	89.0	12.0	48.0	149.0
Michigan	718.0	296.0	117.0	1,131.0
Minnesota	301.0	1,087.0	524.0	1,912.0
Missouri	83.0	78.0	67.0	228.0
New Hampshire	16.0	104.0	6.0	126.0
New Jersey	52.0	—	66.0	118.0
New York	100.0	—	27.0	127.0
Ohio	33.9	—	8.3	42.2
Pennsylvania	110.0	56.0	10.0	176.0
Rhode Island	—	—	1.7	1.7
Vermont	23.0	96.0	7.0	126.0
West Virginia	134.0	107.0	233.0	474.0
Wisconsin	89.0	181.0	3.0	273.0
Total	**1,902.1**	**2,056.0**	**1,452.3**	**5,410.4**

[1]Includes national parks, battlefields, seashore and recreation areas, historic sites and other designations within the National Park System. Non-Federal public and private lands managed by the National Park Service are also included.
[2]Includes national wildlife refuges, wilderness areas, national wildlife waterfowl production areas, coordination areas, fish hatcheries, migratory waterfowl refuges, and administrative sites.
[3]Specially designated areas of the National Forest System include wilderness areas, wild and scenic river areas, primitive areas, scenic and scenic-research areas, recreation areas, game refuges and wildlife preserve areas, monument areas, volcanic monument areas, and historic areas.
Source: AF&PA 2001.

Appendix 6–M. Land in the Northern United States protected under the Forest Legacy Program through August 31, 2000[1]

State	Area	Value	Federal payment
	Acres	-----Dollars-----	
Connecticut	352	390,000	390,000
Illinois	83	344,000	252,000
Massachusetts	1,285	6,279,000	3,462,000
Maryland	668	775,000	0
Maine	31,398	7,293,000	5,793,000
New Hampshire	12,797	5,112,000	1,804,000
New Jersey	1,645	11,712,000	962,000
New York	708	403,000	403,000
Rhode Island	432	920,000	920,000
Vermont	47,940	7,556,000	6,457,000
Total	**97,308**	**40,784,000**	**20,443,000**

[1]Includes conservation easements, donations, and State purchases.
Source: USDA Forest Service 2000b.

Appendix 6–N. Employment and average wages for forestry occupations and workers in agriculture, forestry, fishing, and related work by State in the Northern United States, 1998

Occupation title	Employment	Median hourly	Mean hourly	Mean annual	Mean RSE[1]
		----------Dollars---------			Percent
Choke setters					
West Virginia	N/A	10.73	11.00	22,890	13.50
Fallers and buckers					
Indiana	90	11.68	11.72	24,370	8.30
Maine	440	10.87	10.90	22,680	4.90
Maryland	30	10.13	10.82	22,500	3.70
Michigan	290	9.74	9.57	19,900	3.90
Minnesota	200	12.96	16.18	33,660	3.00
Missouri	50	10.19	10.13	21,060	6.20
New Hampshire	120	12.41	13.50	28,080	9.70
New York	270	10.70	11.54	23,990	3.10
Ohio	130	11.38	10.87	22,610	3.60
Pennsylvania	340	11.27	10.63	22,100	3.40
Vermont	50	11.19	12.85	26,740	23.50
Wisconsin	200	10.45	10.25	21,310	3.60
West Virginia	640	6.73	7.54	15,680	7.80
Total employment and average wages	*2,850*	*10.75*	*11.27*	*23,437*	
First-line supervisors and managers/supervisors—agricultural, forestry, fishing, and related workers					
Connecticut	580	14.72	15.58	32,410	2.30
Delaware	190	10.48	12.10	25,170	4.10
Illinois	1,770	12.99	14.26	29,660	2.50
Indiana	920	12.24	13.36	27,780	1.60
Iowa	250	13.48	15.25	31,720	5.70
Maine	360	13.09	14.14	29,410	7.20
Maryland	950	15.08	15.19	31,600	2.00
Massachusetts	560	14.22	15.88	33,020	2.80
Michigan	1,730	12.56	14.69	30,550	4.20
Minnesota	940	13.27	14.25	29,650	5.80
Missouri	790	12.57	13.36	27,800	1.90
New Hampshire	140	12.28	13.50	28,070	3.70
New Jersey	2,380	14.66	16.72	34,770	4.40
New York	1,920	14.54	16.46	34,230	3.30
Ohio	1,560	12.99	14.20	29,530	2.20
Pennsylvania	1,200	14.40	15.19	31,600	2.10
Rhode Island	410	11.80	12.71	26,450	11.70
Vermont	130	13.93	15.33	31,890	7.40
West Virginia	190	14.47	15.97	33,210	4.10

[1]See footnote on page 220.

Appendix 6–N. Employment and average wages for forestry occupations and workers in agriculture, forestry, fishing, and related work by State in the Northern United States, 1998 (cont.)

Occupation title	Employment	Median hourly	Mean hourly	Mean annual	Mean RSE[1]
		----------Dollars---------			Percent
First-line supervisors and managers/supervisors—agricultural, forestry, fishing, and related workers (cont.)					
Wisconsin	930	14.87	15.52	32,280	1.90
Total employment and average wages	*17,900*	*13.43*	*14.68*	*30,540*	
Forest and conservation workers					
Delaware	40	8.49	11.54	24,000	2.30
Illinois	390	11.43	11.09	23,070	5.70
Indiana	270	6.93	7.95	16,530	3.10
Iowa	710	7.82	8.87	18,440	5.80
Maine	50	11.65	11.60	24,130	2.10
Massachusetts	90	14.80	14.85	30,890	5.80
Michigan	190	15.33	15.97	33,220	1.10
Minnesota	390	14.00	13.84	28,790	3.90
New Hampshire	50	13.95	14.46	30,070	3.40
New Jersey	140	15.42	16.84	35,020	2.90
Ohio	580	17.09	18.68	38,850	1.70
Pennsylvania	110	12.63	13.32	27,700	3.80
Vermont	100	9.20	10.57	21,980	1.30
West Virginia	210	12.52	12.74	26,500	3.90
Wisconsin	510	15.01	14.93	31,050	1.20
Total employment and average wages	*3,830*	*12.42*	*13.15*	*27,349*	
Forest fire inspectors and prevention specialists					
Illinois	N/A	13.47	15.29	31,800	10.80
Missouri	100	19.06	18.26	37,980	2.40
New Jersey	50	15.56	18.12	37,680	4.50
New York	190	15.11	14.79	30,760	1.90
Pennsylvania	80	15.76	14.48	30,120	1.80
Total employment and average wages	*420*	*15.79*	*16.19*	*33,668*	
Foresters and conservation scientists					
Illinois	400	17.86	18.78	39,050	1.20
Indiana	320	19.12	19.72	41,020	1.60
Iowa	330	20.92	20.91	43,490	1.80
Maine	110	19.99	20.95	43,580	1.70
Maryland	260	18.62	21.74	45,220	1.70
Michigan	1,250	21.40	21.00	43,690	2.30
Minnesota	720	21.18	21.51	44,730	1.00
Missouri	590	21.07	21.82	45,390	1.20

[1]See footnote on page 220.

Appendix 6–N. Employment and average wages for forestry occupations and workers in agriculture, forestry, fishing, and related work by State in the Northern United States, 1998 (cont.)

Occupation title	Employment	Median hourly	Mean hourly	Mean annual	Mean RSE[1]
		----------Dollars---------			Percent
Foresters and conservation scientists (cont.)					
New Jersey	220	22.77	23.36	48,580	2.40
New York	560	21.30	21.62	44,960	4.30
Ohio	660	20.30	20.64	42,930	2.00
Pennsylvania	690	20.03	19.85	41,280	3.00
Vermont	90	19.35	20.41	42,460	1.70
West Virginia	300	17.60	18.67	38,820	1.20
Wisconsin	880	20.54	22.03	45,830	1.80
Total employment and average wages	*7,380*	*20.14*	*20.87*	*43,402*	
Log graders and scalers					
Indiana	80	10.76	14.18	29,500	8.30
Maine	90	10.93	11.32	23,550	3.30
Michigan	90	10.33	10.48	21,800	3.20
Minnesota	N/A	9.92	10.61	22,080	1.30
Missouri	150	9.55	11.05	22,980	5.80
New Hampshire	40	12.27	12.42	25,830	3.80
New York	90	10.40	12.20	25,370	3.50
Ohio	100	12.22	13.54	28,160	4.00
Pennsylvania	120	10.88	11.83	24,600	2.70
Vermont	30	11.78	12.05	25,060	2.90
West Virginia	140	10.46	10.34	21,500	2.50
Wisconsin	230	11.99	13.23	27,520	6.60
Total employment and average wages	*1,160*	*10.96*	*11.94*	*24,829*	
Logging tractor operators					
Illinois	30	8.00	8.88	18,480	5.50
Indiana	120	10.70	10.69	22,240	6.40
Maine	800	11.08	11.80	24,540	3.60
Maryland	100	9.02	9.68	20,130	5.80
Michigan	440	11.28	11.31	23,530	4.00
Minnesota	240	11.12	10.39	21,610	10.50
Missouri	120	10.21	10.02	20,830	6.10
New Hampshire	170	11.07	12.26	25,500	6.70
New York	130	11.25	11.49	23,900	4.50
Ohio	160	10.55	10.62	22,090	2.40
Pennsylvania	370	9.23	9.53	19,810	3.40
Vermont	60	11.07	11.19	23,280	5.40
Wisconsin	390	10.67	10.80	22,450	3.00

[1]See footnote on page 220.

Appendix 6–N. Employment and average wages for forestry occupations and workers in agriculture, forestry, fishing, and related work by State in the Northern United States, 1998 (cont.)

Occupation title	Employment	Median hourly	Mean hourly	Mean annual	Mean RSE[1]
		----------Dollars---------			Percent
Logging tractor operators (cont.)					
West Virginia	250	8.48	8.78	18,250	3.40
Total employment and average wages	*3,380*	*10.27*	*10.53*	*21,903*	
Log-handling equipment operators					
Illinois	50	8.56	9.29	19,320	7.80
Indiana	150	7.74	8.00	16,630	4.70
Maine	480	10.94	11.05	22,980	5.20
Maryland	70	8.19	8.93	18,580	4.00
Michigan	630	10.74	11.12	23,130	3.90
Minnesota	730	12.68	12.35	25,690	1.90
Missouri	80	7.92	8.29	17,240	4.10
New Hampshire	110	11.32	11.68	24,290	7.30
New York	220	9.53	9.96	20,710	3.90
Ohio	280	10.33	10.58	22,000	2.50
Pennsylvania	450	9.10	9.17	19,060	2.70
Vermont	50	11.97	11.27	23,450	3.00
West Virginia	440	8.36	9.10	18,930	4.40
Wisconsin	840	10.03	11.84	24,620	3.10
Total employment and average wages	*4,580*	*9.82*	*10.19*	*21,188*	
All other timber cutting and related logging workers					
Indiana	300	11.33	11.16	23,200	2.10
Maryland	90	8.04	8.98	18,690	4.80
Michigan	N/A	8.03	9.14	19,010	2.50
New York	160	23.55	24.45	50,860	1.80
Ohio	N/A	10.16	10.13	21,080	1.60
West Virginia	40	9.22	10.34	21,510	5.10
Wisconsin	40	10.07	11.51	23,940	4.00
Total employment and average wages	*630*	*11.49*	*12.24*	*25,470*	
All other agricultural, forestry, fishing, and related workers					
Connecticut	420	10.43	11.89	24,740	1.60
Delaware	330	8.66	10.49	21,810	1.50
Illinois	3,700	10.93	11.78	24,490	1.90
Indiana	1,260	9.15	10.24	21,290	2.50
Iowa	2,190	9.12	10.17	21,140	3.10
Maine	690	7.77	8.63	17,940	2.10
Maryland	760	10.22	10.93	22,740	2.20
Massachusetts	880	10.87	11.82	24,580	1.80

[1]See footnote on page 220.

Appendix 6–N. Employment and average wages for forestry occupations and workers in agriculture, forestry, fishing, and related work by State in the Northern United States, 1998 (cont.)

Occupation title	Employment	Median hourly	Mean hourly	Mean annual	Mean RSE[1]
		----------Dollars---------			Percent
All other agricultural, forestry, fishing, and related workers (cont.)					
Michigan	2,100	9.64	11.65	24,240	2.90
Minnesota	1,810	10.57	12.25	25,480	2.10
Missouri	1,090	7.61	9.32	19,380	3.90
New Hampshire	170	10.93	11.84	24,630	2.30
New Jersey	1,210	9.28	11.35	23,600	3.00
New York	2,010	10.38	11.59	24,110	1.40
Ohio	2,470	11.25	11.89	24,720	2.40
Pennsylvania	3,570	9.50	10.21	21,230	3.00
Rhode Island	N/A	7.56	8.67	18,030	2.90
Vermont	80	12.51	13.11	27,280	3.00
West Virginia	440	9.37	10.34	21,520	2.10
Wisconsin	1,870	8.52	9.57	19,900	1.30
Total employment and average wages	*27,050*	*9.71*	*10.89*	*22,643*	

[1]Relative standard error (RSE) of the mean wage is a measure of the reliability of a survey statistic. The smaller the RSE, the more precise the estimate.
Note: N/A = data not available
Source: USDL Bureau of Labor Statistics 1998a.

Appendix 6–O. Average annual salaries for State forestry agency staff in the Northern United States and the District of Columbia, fiscal year 1998

State	State forester	Regional (or State staff) forester	District forester	Service or field forester	Entry-level forester	Forestry technician
			Dollars			
Connecticut	87,500	55,100	55,100	50,200	43,700	34,800
Delaware	45,600	40,000	—	35,100	30,500	22,900
District of Columbia	66,000	—	—	—	—	30,000
Illinois	72,300	60,000	35,400	—	26,600	27,600
Indiana	76,877	45,710	36,784	—	29,143	
Iowa	80,000	55,000	42,000	42,000	29,000	28,000
Maine	64,000	—	—	40,000	30,000	—
Maryland	66,221	49,359	42,400	36,700	24,524	26,900
Massachusetts	72,000	49,000	47,000	45,000	37,000	32,000
Michigan	75,240	53,592	53,790	46,200	28,314	30,360
Minnesota	103,700	88,000	69,000	58,800	35,000	48,000
Missouri	82,000	58,238	52,573	37,414	21,960	29,450
New Hampshire	62,683	43,407	40,581	—	31,283	23,442
New Jersey	75,000	55,000	40,000	33,000	28,000	24,000
New York	95,735	57,537	49,000	44,739	27,141	26,537
Ohio	69,500	52,083	52,083	33,010	24,814	23,920
Pennsylvania	85,000	67,500	60,000	37,500	29,000	30,000
Rhode Island	72,000	50,000	—	38,000	26,000	32,000
Vermont	64,000	55,000	44,000	37,000	27,000	23,000
West Virginia	65,000	46,500	42,900	28,000	21,200	26,900
Wisconsin	71,000	49,000	—	37,500	27,700	29,000

Source: National Association of State Foresters 1998.

Appendix 6–P. State-reported incidence rates[1] (cases per 100 full-time employees) of nonfatal occupational injuries and illnesses by industry, 1998

State[2]	Average annual employment[3]	Injuries and illnesses combined: Total cases	Injuries and illnesses combined: Lost workday cases: Total[4]	Injuries and illnesses combined: Lost workday cases: With days away from work[5]	Injuries and illnesses combined: Cases without lost work days	Injuries alone: Total cases	Injuries alone: Lost workday cases: Total[4]	Injuries alone: Lost workday cases: With days away from work[5]	Injuries alone: Cases without lost work days
	Thousands								
Agriculture, forestry, and fishing[6]									
Connecticut	16.4	9.9	5.0	3.3	4.9	9.4	4.9	3.2	4.7
Delaware	3.7	6.4	2.7	2.3	3.7	6.4	2.7	2.3	3.6
Illinois	48.2	9.0	4.3	3.3	4.6	8.7	4.2	3.2	4.4
Indiana	25.9	7.3	3.2	2.0	4.0	7.1	3.2	2.0	3.9
Iowa	16.9	12.0	5.0	4.1	7.0	11.5	4.8	3.9	6.7
Maine	6.5	12.5	5.1	2.9	7.4	12.2	4.9	2.9	7.3
Maryland	20.6	6.7	3.2	2.7	3.5	6.5	3.1	2.6	3.4
Massachusetts	21.5	10.8	3.9	3.4	6.9	10.6	3.8	3.3	6.8
Michigan	42.4	6.2	3.3	2.6	2.9	5.9	3.2	2.6	2.8
Minnesota	23.9	9.4	4.7	3.0	4.7	9.2	4.6	2.9	4.6
Missouri	23.6	7.9	3.7	2.6	4.1	7.5	3.6	2.5	3.9
New Jersey	N/A	3.0	2.5	3.5	6.4	2.9	2.5	2.5	3.4
New York	47.2	4.8	2.9	2.9	1.9	4.7	2.9	2.8	1.8
Rhode Island	3.1	9.8	6.5	6.2	3.3	9.0	5.6	5.4	3.3
Vermont	3.4	2.5	1.5	1.5	1.1	2.5	1.5	1.5	1.0
West Virginia	4.2	10.6	3.3	2.9	7.3	10.4	3.3	2.9	7.1
Wisconsin	25.9	10.5	3.8	3.1	6.8	10.2	3.6	3.0	6.6
Northern U.S.	333.4	139.3	64.6	52.3	80.5	134.7	62.4	49.5	75.3
National	1,815.1	7.9	3.9	3.0	4.0	7.6	3.8	2.9	3.8
Lumber and wood products (SIC code[7] 24)									
Delaware	0.5	16.7	10.2	8.1	6.5	16.3	9.8	7.7	6.5
Illinois	13.0	12.0	4.0	3.4	8.0	12.0	4.0	3.4	8.0
Indiana	30.6	21.5	9.2	4.6	12.3	20.6	8.8	4.4	11.8
Iowa	12.5	15.6	9.2	5.4	6.4	15.2	9.0	5.2	6.3
Maine	10.6	16.0	8.4	3.5	7.6	14.2	7.5	3.3	6.8
Maryland	4.5	8.2	3.3	3.2	4.9	8.1	3.3	3.2	4.8
Massachusetts	4.1	9.5	6.1	4.9	3.4	9.4	6.0	4.9	3.4
Michigan	17.5	12.1	6.6	3.7	5.5	11.6	6.3	3.5	5.4
Minnesota	20.8	15.8	7.7	3.9	8.1	14.0	6.8	3.5	7.2
New Jersey	N/A	16.4	8.7	7.5	7.7	16.4	8.7	7.5	7.7
New York	14.5	8.8	7.3	6.9	1.5	8.7	7.2	6.8	1.5
Rhode Island	1.2	10.7	6.8	4.7	4.0	10.7	6.8	4.7	4.0
West Virginia	10.3	17.8	10.7	9.6	7.1	16.3	10.1	9.2	6.2
Wisconsin	31.7	20.0	10.3	6.1	9.7	18.6	9.6	5.8	9.1
Northern U.S.	987.8	214.3	115	79.3	99.1	204.7	110	76.8	94.8
National	816.0	13.2	6.8	3.8	6.4	12.6	6.5	3.7	6.1

[1 2 3 4 5 6 7]See footnotes on page 224.

Appendix 6–P. State-reported incidence rates[1] (cases per 100 full-time employees) of nonfatal occupational injuries and illnesses by industry, 1998 (cont.)

State[2]	Average annual employment[3]	Injuries and illnesses combined: Total cases	Injuries and illnesses combined: Lost workday cases: Total[4]	Injuries and illnesses combined: Lost workday cases: With days away from work[5]	Injuries and illnesses combined: Cases without lost work days	Injuries alone: Total cases	Injuries alone: Lost workday cases: Total[4]	Injuries alone: Lost workday cases: With days away from work[5]	Injuries alone: Cases without lost work days
	Thousands								
Logging (SIC code[7] 241)									
Maine	2.5	6.8	2.9	2.9	3.9	5.6	2.9	2.9	2.7
Sawmills and planing mills (SIC code[7] 242)									
Maine	2.6	15.4	9.9	4.3	5.6	14.1	8.7	4.3	5.3
Wisconsin	4.8	19.4	11.0	8.7	8.5	19.0	10.7	8.6	8.3
Northern U.S.	7.4	34.8	20.9	13.0	14.1	33.1	19.4	12.9	13.6
Miscellaneous wood products (SIC code[7] 249)									
Maine	3.4	17.9	5.4	3.2	12.4	14.9	4.1	2.6	10.8
Paper and allied products (SIC code[7] 26)									
Iowa	6.1	7.2	4.5	0.7	2.6	6.9	4.3	0.6	2.6
Maine	14.4	8.8	3.7	1.1	5.1	7.8	3.3	1.0	4.5
Maryland	7.5	4.1	2.6	1.0	1.5	4.0	2.6	1.0	1.4
Massachusetts	19.2	8.0	5.3	3.1	2.7	7.5	4.9	2.9	2.6
Michigan	21.0	9.5	5.3	2.9	4.2	8.6	4.6	2.5	4.0
Minnesota	30.8	5.9	2.8	1.1	3.1	5.2	2.5	1.0	2.7
Missouri	13.5	12.4	7.3	2.8	5.1	11.8	6.9	2.5	4.9
New Jersey	N/A	7.4	3.9	2.6	3.5	7.2	3.8	2.6	3.4
New York	31.8	8.6	4.7	3.8	3.9	8.3	4.6	3.7	3.7
Rhode Island	1.9	12.8	7.7	2.5	5.0	12.3	7.5	2.5	4.8
Vermont	2.1	5.7	3.5	3.0	2.2	5.2	3.1	2.6	2.0
West Virginia	1.2	18.0	9.8	9.8	8.2	16.3	9.0	9.0	7.3
Wisconsin	53.1	7.6	3.6	2.0	4.0	6.9	3.4	1.9	3.5
Northern U.S.	202.6	116.0	64.7	36.4	51.1	108.0	60.5	33.8	47.4
National	678.6	7.1	3.7	2.0	3.3	6.6	3.6	1.9	3.1
Paper mills (SIC code[7] 262)									
Maine	11.9	8.8	3.9	1.1	4.9	7.6	3.4	1.1	4.2
Michigan	5.9	7.9	4.1	3.1	3.8	7.5	3.9	3.0	3.7
Minnesota	5.3	6.2	2.2	1.6	4.0	5.9	2.2	1.6	3.8
New York	8.2	13.5	5.5	3.4	N/A	N/A	5.5	3.4	N/A
Wisconsin	29.3	6.4	2.8	1.5	3.7	5.6	2.6	1.4	3.0
Northern U.S.	60.6	42.8	18.5	10.7	16.4	26.6	17.6	10.5	14.7

[1 2 3 4 5 7]See footnotes on page 224.

Appendix 6–P. State-reported incidence rates[1] (cases per 100 full-time employees) of nonfatal occupational injuries and illnesses by industry, 1998 (cont.)

[1]The incidence rates represent the number of injuries and illnesses per 100 full-time workers and were calculated as:
(N/EH) × 200,000, where
N = number of injuries and illnesses
EH = total hours worked by all employees during the calendar year
200,000 = base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year)
[2]No State data available for New Hampshire, Ohio, or Pennsylvania.
[3]Employment is expressed as an annual average and is derived primarily from the Bureau of Labor Statistics State Covered Employment and Wages program. Employment in private households (SIC 88) is excluded.
[4]Total lost workday cases involve days away from work, or days of restricted work activity, or both.
[5]Cases that result in days away from work with or without restricted work activity.
[6]Excludes farms with fewer than 11 employees.
[7]Standard Industrial Classification Manual, 1987 edition.
Note: Components may not add to totals due to rounding.
N/A = data not available
Source: USDL Bureau of Labor Statistics 1998c.

Criterion 7

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

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

Constance Carpenter[1]

Introduction

An effective legal, institutional, and economic framework achieves broad environmental, social, and economic goals. It is responsive to the varying roles and needs of public land managers and users, industry, and nonindustrial landowners. It establishes systems to measure and monitor changes in the conservation and management of forests and supports research and development directed to the improvement of forest management and the delivery of forest goods and services.

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. Some key demographic trends include increases in population, increases in the average age of the population, increases in cultural diversity, and increases in the proportion of urban to suburban residents among the population (USDC Bureau of the Census 1997).

The Northern U.S. population in 1990 was almost 42 percent of the country's total or nearly 113 million people. The Northern United States has 57 cities with populations over 100,000. Between 1960 and 1990, the population in the Northern United States increased by over 15 million people. Growth occurred in cities of all sizes between 1990 and 1999. For example, the New York City metropolitan area is the most populated in the United States with over 8.7 million people in 1999. This reflects an increase of almost 166,000 people (1.9 percent) since 1990. The Madison, Wisconsin, metropolitan area, with over 428,500 people, increased by almost 61,500 people in the same period. This is a 16.7-percent increase in the local population and over a third of the growth experienced by the New York City metropolitan area (figures 7.1(a) and 7.1(b)) (USDC Bureau of the Census 2000).

Along with population growth, technology is changing rapidly, especially in communications, computer analysis, and forest product manufacturing and harvesting. Capital, products, and information flow more quickly and freely across State, regional, national, and international borders than ever before, and public attitudes toward management and investment in forest resources are varied. External factors such as the strength of the American dollar, trade balances, and uncertain inflationary forces affect efforts to achieve sustainability.

Landownership in the Northern United States

Traditionally, forest lands are categorized as public or private. These distinctions are evident in legal, institutional, and economic systems and in continuing discussions over the role of public and private forest lands in meeting various sustainability goals. According to a 1994 survey, the majority of forest land in the Northern United States, approximately 130 million

[1]USDA Forest Service, Northeastern Area State and Private Forestry, Durham, NH

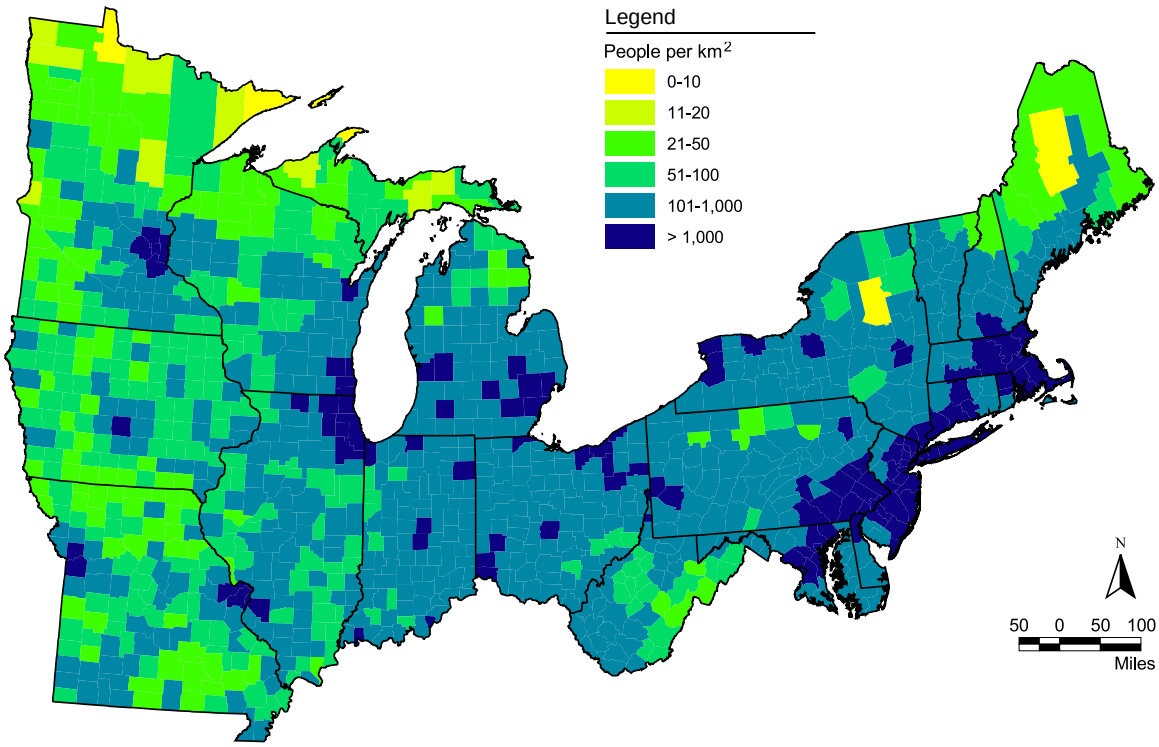

Figure 7.1(a). **Population density by county in the Northern United States, 1999** (Data source: Population data estimated by CACI International, Inc., Arlington, VA).

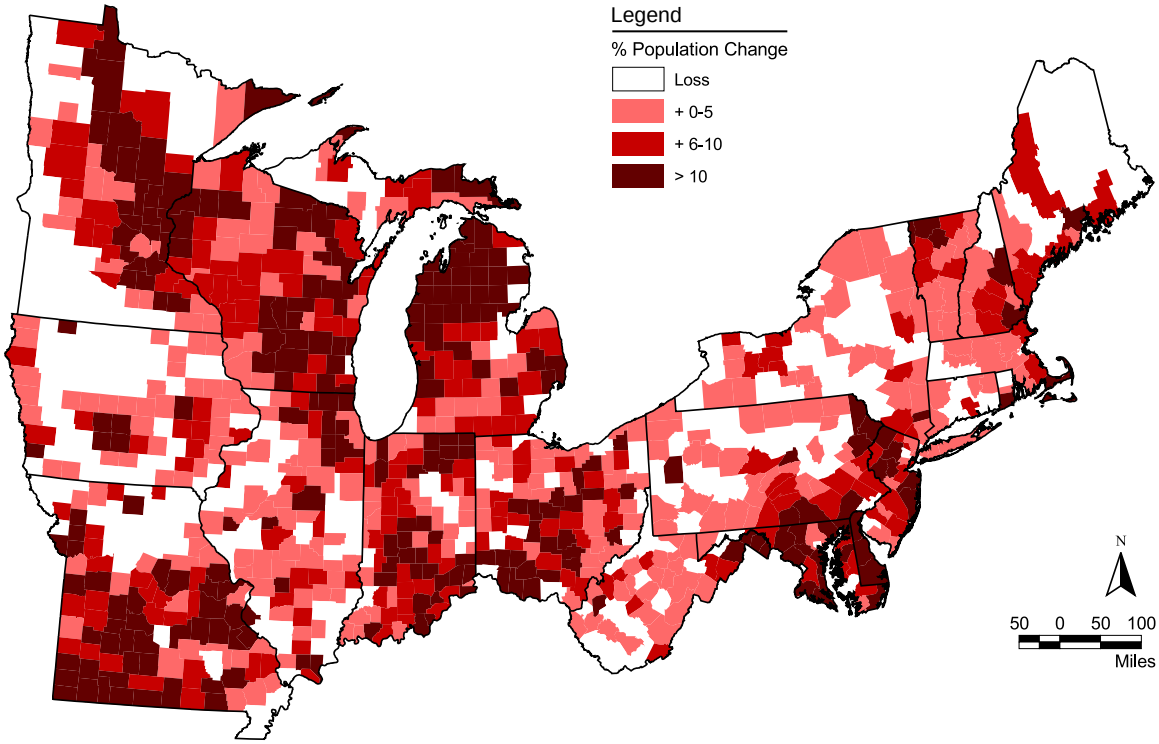

Figure 7.1(b). **Population change by county in the Northern United States from 1990 to 1999** (Data sources: 1990 population: U.S Census Bureau; 1999 population estimates: CACI International, Inc., Arlington, VA).

acres (78 percent), was privately owned, an increase of 16 million acres from 1978 (Birch 1996a). 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.

Increases in the rate at which forest land is bought and sold in the Northern United States are raising concern that private landowners will not invest in the long-term stewardship necessary to nurture healthy forests. According to a 1994 survey, more than 33 percent of current Northern U.S. forest landowners acquired forest land for the first time since 1978. These owners control 24 percent of private forest land (figure 7.2) (Birch 1996a). Many people who first acquired forest land between 1970 and 1977 are selling their land and, as a group, have smaller landholdings on average than in the past. The age profile of the Nation

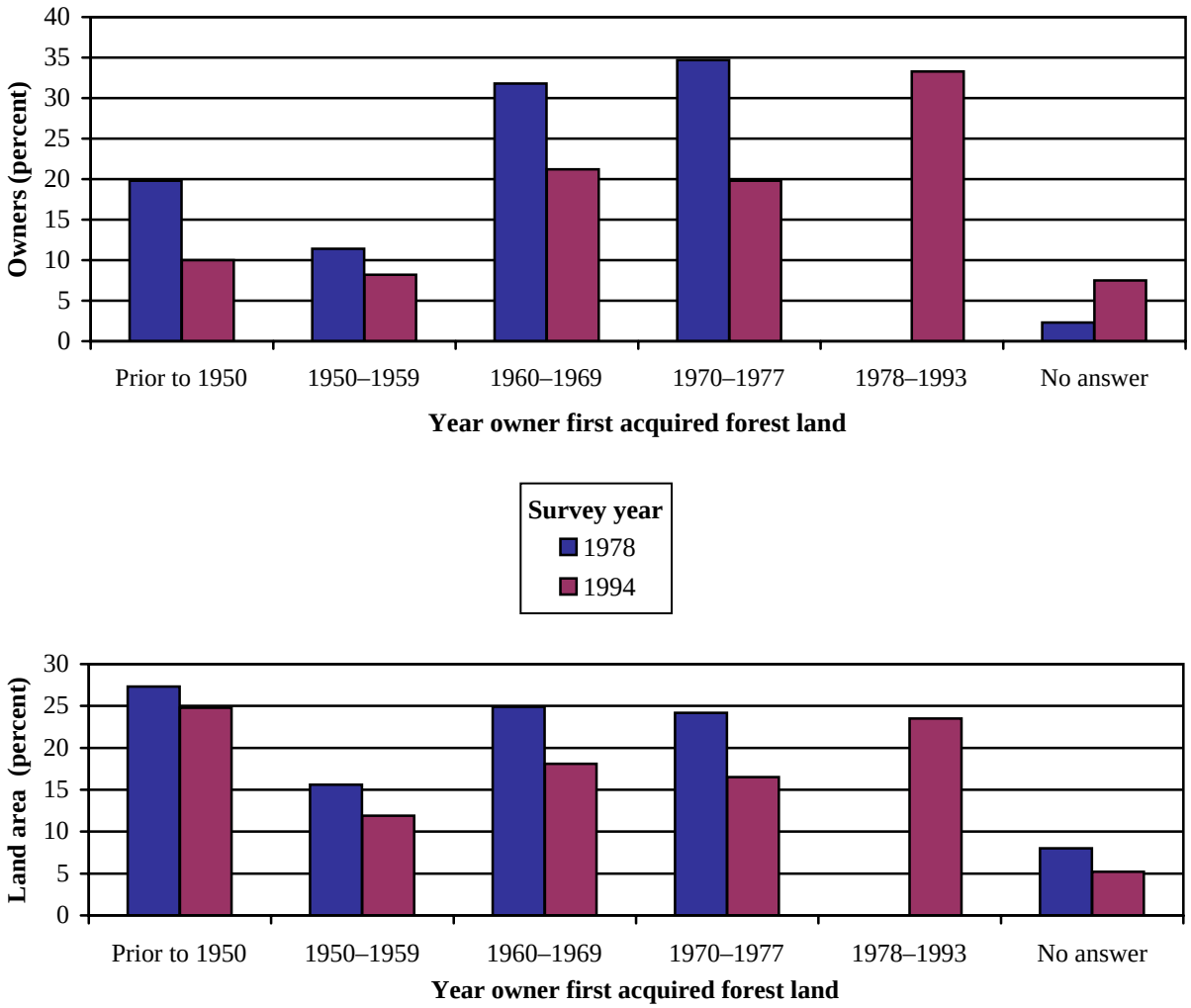

Figure 7.2. **Trends in distribution of private ownerships, by year owner first acquired forest land, in the Northern United States** (Birch 1996a). Landowner surveys were conducted in 1978 and 1994. The year that owners first acquired forest land is shown as a percentage of the total number of owners (above) and the total land area owned (below).

is reflected in forest land ownership patterns of the Northern United States. For example, more retirees own forest land than in the past. They make up over 30 percent of nonindustrial private forest landowners and hold over 30 percent of the nonindustrial forest land.

Public lands contribute many of the same benefits as private lands but also provide amenities not always available from private lands. For example, public lands may provide large blocks of contiguous forest that support primitive recreation and wilderness experiences, provide reference sites for forest health monitoring and long-term ecological studies, and provide opportunities to showcase sustainable 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 1996a). 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 administers almost 12 million acres of land in the Northern United States (USDA Forest Service 1997b) (figure 7.3, appendix 7–A).

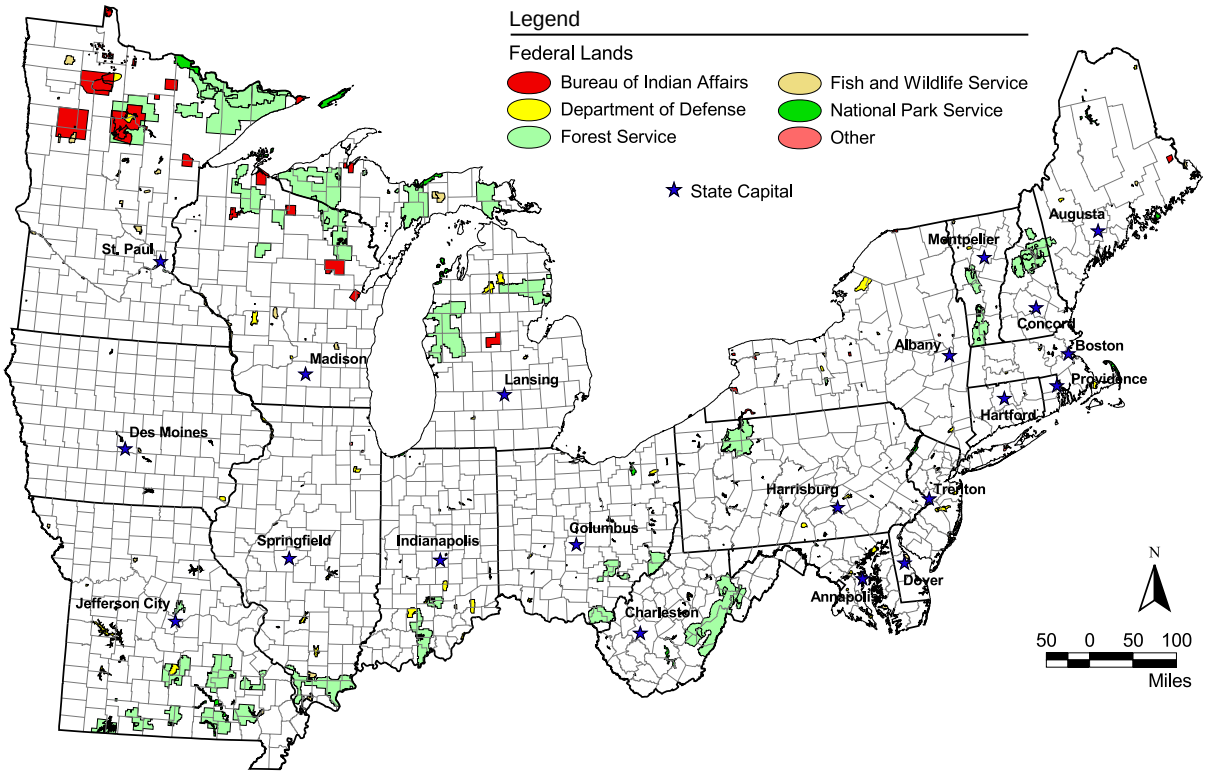

Figure 7.3. **Federal land holdings in the Northern United States**. Among Federal agencies, the USDA Forest Service holds the most land in the Northern United States—nearly 12 million acres (USDA Forest Service 1998b).

Public ownership is one means of providing for public interests. Another means is for nongovernment organizations to dedicate land to the interests and uses of the general public. Governmental and nongovernmental organizations also may purchase select land and water rights from private landowners to guarantee continued public benefits.

Indicators 48 through 52 refer to the extent to which the legal framework (laws, regulations, and guidelines) supports the conservation and sustainable management of forests.

An extensive legal framework supports conservation and sustainable management of forests from the Federal to the local level.

Federal Authority

Applicable national laws and regulations protect public benefits from forests and prevent damage to natural resources such as wetlands, water and air quality, wildlife, and threatened and endangered species. Tax, business, and health and safety laws and regulations also affect private forestry, forest-based industries, and community sustainability. Existing laws set forth the legal and desired cooperative relationships among Federal, State, and local agencies. *The Principal Laws Relating to Forest Service Activities* (USDA Forest Service 1993) lists most of the laws referenced in this chapter.

United States environmental policy is set forth in the National Environmental Policy Act of 1969 (P.L. 91–190, 83 Stat. 852; 42 U.S.C. 4321 (note), 4321, 4331–4335, 4341–4346, 4346a-b, 4347) (NEPA). It is national policy "to encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality." NEPA requires interdisciplinary analysis of the impacts of all Federal actions with potential to affect the environment.

Federal law established the USDA Forest Service with a system of public forests and grasslands, programs for research, cooperative programs for State and private forests, and international forestry assistance. Forest Service programs for State and private lands are voluntary rather than regulatory and are administered in cooperation with State forestry agencies. Federal regulatory programs affecting private forest lands are administered by agencies such as the Environmental Protection Agency, the Army Corps of Engineers, and the Fish and Wildlife Service. For example, forest chemicals and pesticides are approved and regulated by the Environmental Protection Agency. These agencies implement their programs in cooperation with State agencies.

State Authority

Laws and regulations developed at the State level are more common today than in the past, although alternatives are popular. Advocates for State regulation see it as more pragmatic than Federal or local regulations. The premise is that State regulations can be adjusted to local conditions more easily than can a national program and can provide some consistency for businesses that may otherwise be required to comply with varying local ordinances. For example, Maine and Connecticut have comprehensive forest practice laws. Massachusetts has the Forest Cutting Practices Act (1982). In Maryland, forestry practice is one component of a broader State regulatory system.

Not all State regulatory programs deal with forestry exclusively (e.g., water quality regulation deals with many sources of pollution) and not all regulations are enforced through the State forestry agency (e.g., the State department of agriculture may oversee insect and disease control). State regulatory programs generally protect forests from wildfire, insects, and disease; protect wildlife, including threatened and endangered species; and encourage reforestation. Alternatives to outright regulation of forest practices include nonregulatory or voluntary best management practice programs, the purchase of conservation easements, and incentive programs such as cost-share payments, preferential property or income tax treatment, technical assistance, extension, and environmental education programs (table 7.1).

Table 7.1. **Number of States with forest resource conservation programs in the Northern United States**.[1] States rely on education programs and technical assistance more than regulation to conserve and protect forest values (Ellefson and others 1995).

Type	Protect water quality	Promote reforestation	Improve timber harvesting methods	Protect from wildfire, insects, and diseases	Protect wildlife and rare and endangered species	Enhance recreation and aesthetics
Regulatory programs	13	7	8	11	8	3
Voluntary guidelines	18	7	11	7	9	7
Tax incentives	9	11	8	6	3	5
Fiscal incentives	13	15	7	8	13	13
Technical assistance	21	20	20	20	19	21
Education programs	20	20	20	20	21	19

[1]This summary excludes Ohio and includes Virginia and Kentucky.

Local Authority

Counties, cities, and towns have authority to regulate land uses and activities (table 7.2). Municipalities cannot usurp regulatory rights reserved by the State, but can pass laws that are more restrictive than State law. Regulation through local zoning is becoming more common as suburban development continues. Pennsylvania and New Hampshire prohibit municipal zoning and planning authorities from limiting timber harvest activities. Maine and Connecticut allow for local regulations.

Table 7.2. **Counties, cities, and townships 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	—

Indicator 48. Clarifies property rights, provides for appropriate land tenure arrangements, recognizes customary and traditional rights of indigenous people, and provides means of resolving property disputes by due process

In the Northern United States, where the majority of the land is privately owned, the issue of property rights is important. Private lands include tribal lands.

Landowner Rights and Responsibilities

The United States has a political tradition based on individual freedoms and rights; however, each person has a civic responsibility to contribute to public health, safety, and welfare. The fifth amendment of the Constitution prohibits the government from taking private property for public use without just compensation. The 14th amendment relegates police power to the States to prevent private and public nuisances, in essence giving government the power to regulate land use. The question raised is how much can property use or value be restricted by regulation before it is considered a taking? Case law is important in setting the balance between civic responsibility and private property rights. Delaware, Indiana, Missouri, and West Virginia have laws requiring State or local agencies to assess the potential for a taking of private property rights before government action can be initiated (Zhang 1996). Public agency responsibilities for resources such as wildlife and water quality that are dependent on stewardship of private as well as public land add another element of complexity to this debate.

Landowner Rights and Responsibilities

Rights:

- To control access to the property and exclude or accept public use.
- To make economic use of the property, including harvesting of trees and other natural resources.
- To use, sell, transfer, or otherwise dispose of the property freely.
- To seek quiet use and enjoyment of property free from unreasonable interference by others.

Responsibilities:

- To pay applicable taxes on the land and income generated from the use of resources.
- To comply with applicable environmental laws to protect resources such as soil and water.
- To consider the impact on neighboring landowners, communities, and the public when making significant land-management decisions (National Research Council 1998).

National Property Rights Trends

The USDA Forest Service identified four national trends affecting property rights:

- An increase in the regulatory, legislative, and judicial actions that affect property rights, either by expanding or diminishing them.
- Significant changes in patterns of ownership and use.
- Extension of economic valuations to new types of natural resources (e.g., landowners leasing land for hunting, States subsidizing landowners to protect specific resources, collectors paying for permits to collect nontimber forest products).
- Increasing autonomy for Native American tribes (USDA Forest Service 1997a).

Tribal Lands

Tribal lands are private lands, a claim reinforced through the National Indian Forest Resources Management Act (1990). The act makes application of previously existing statutes such as the National Environmental Policy Act and the Endangered Species Act of 1973

controversial because they require action by the Bureau of Indian Affairs (BIA) instead of solely by the tribes as would be the case for private lands. Tribes control timber harvesting and other land uses on their property; however, unlike on most private lands, the United States has a trust responsibility to protect, conserve, use, manage, and enhance tribal forest land in perpetuity, including its economic and other benefits. This responsibility includes the provision of essential primary and secondary forest roads.

Legal doctrines regarding Native American rights are complicated. Individual Federal and State treaties differ, and tribes have rights of self-government that may exclude some regulation by States. For example, some treaties recognize specific tribal hunting and gathering rights.

Takings Under the Endangered Species Act

The Endangered Species Act of 1973 (P.L. 93–205, 87 Stat. 884, as amended: 16 U.S.C. 1531–1536, 1538–1540) administered by the U.S. Fish and Wildlife Service has received a lot of attention because of the implications for property rights. The law authorizes the agency to protect threatened and endangered wildlife species from private "taking." This includes activities that "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect" species. Forestry activities resulting in destruction or modification of endangered species habitat could be a violation of the Endangered Species Act (ESA).

In 1982, the ESA was amended so that "incidental take" permits could be issued for otherwise lawful activities, such as forestry, that could affect threatened and endangered species. The permitting process involves the development of a habitat conservation plan that is subject to public review under NEPA. Private stakeholders are to be part of the process of developing habitat conservation plans, and appeals can be filed to resolve grievances. Usually forestry activities can be designed so that no "taking" occurs, thus no permit would be required.

Examples of Take Permits

Three incidental take permits had been issued under the Endangered Species Act in the Northern United States as of June 1999: a 2-year permit for 200 coastal miles affecting the piping plover (*Charadrius melodus*) in Massachusetts, a 50-year permit for 56 acres affecting the Delmarva fox squirrel (*Sciurus niger cinereus*) in Maryland, and a 30-year permit for 10.6 acres affecting the Karner blue butterfly (*Lycaeides melissa samuelis*) in Wisconsin.

The most ambitious habitat conservation plan in the Northern United States is a 10-year statewide plan for the Karner blue butterfly being developed in Wisconsin through a Federal, State, county, industry, and utility partnership (USDI Fish and Wildlife Service 1999).

Forest Conservation and Preservation Instruments

A variety of legal instruments exist to preserve specific forest conditions regardless of ownership. These include conservation easements, placement of 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 and willing seller basis.

The USDA Forest Service Forest Legacy Program was authorized to protect environmentally important forests from conversion to nonforest uses. From when it was first funded in 1992 to 1999, 63,000 acres were protected in nine of the Northern United States. Protection is usually accomplished with conservation easements, but tracts can be purchased outright. States and other organizations contribute far more money than this to conservation easement programs, but the Forest Legacy Program is the only one devoted exclusively to the conservation of forest land.

Indicator 49. Provides for periodic forest-related planning, assessment, and policy review that recognizes the range of forest values, including coordination with relevant sectors

A variety of laws, regulations, and guidelines are in place to support multiple resource assessments of forest land, and review of Federal and State land and resource management planning and policy. The laws collectively recognize a wide range of forest values. At the same time, statutory goals and agency priorities differ, which leads to a complex web of planning and assessment protocols, and varying degrees of required public involvement. Coordination of the many laws, programs, policies, and regulations that affect natural resources is an onerous task, and reconciliation generally falls to local planning and assessment groups.

Federal Laws

NEPA requires interdisciplinary environmental and social assessments for Federal projects, including consideration of long-term and cumulative effects. Several laws are directed mainly at USDA Forest Service activities. The Forest and Rangeland Renewable Resources Planning Act of 1974 requires the preparation of a strategic plan for Forest Service activities every 5 years based on an assessment of renewable natural resources on all landownerships every 10 years. The Multiple Use-Sustained Yield Act of 1960 (MUSYA) establishes the multiple-use and sustained-yield policies for management of the national forests and grasslands. The National Forest Management Act of 1976 (NFMA) and subsequent amendments provides standards and guidelines for national forest planning and management. Under this act, national forests establish desired future conditions that include objectives for forest type, composition, location and amounts of various facilities, vegetative conditions, and other aspects of ecosystems that will be created over the long run.

The Cooperative Forestry Assistance Act of 1978 (P.L. 95–313, 92 Stat. 365 as amended; 16 U.S.C. 2101 (note), 2101–2103, 2103a, 2103b, 2104–2105) that guides the Federal-State forestry partnership, authorizes ". . . financial, technical, and related assistance to State Foresters or equivalent State officials in the assembly, analysis, display, and reporting of

State forest resource data, in training of State forest resources planners, and in participating in natural resources planning at the State and Federal levels" (Section 8(b)). Assistance is extended only upon request by State Foresters or equivalent State officials (Section 8(a)). Each of the Northern United States has developed at least one comprehensive State forest resource plan, but many are outdated (appendix 7–B). Comprehensive plans developed under guidelines of the Cooperative Forestry Assistance Act must be multidisciplinary and include a public involvement component.

Programmatic planning is probably the most prevalent form of planning conducted by organizations. Program plans are most effective when developed to carry forward recommendations in a strategic, comprehensive plan, developed with public involvement.

The U.S. Fish and Wildlife Service must prepare a comprehensive conservation plan for each refuge under the National Wildlife Refuge System Improvement Act of 1997. The agency is required to conduct assessments to identify "critical habitat" for threatened and endangered species and to develop and monitor recovery plans under the Endangered Species Act of 1973 (figure 7.4). The Federal Land Policy and Management Act of 1976 (FLPMA) governs Bureau of Land Management land. The National Indian Forest Resources Management Act (1990) provides for planning for multiple values on forested tribal lands. The Sikes Improvement Act of 1997 requires an integrated natural resource management plan for each military installation with significant natural resources, to be developed in cooperation with the U.S. Fish and Wildlife Service and the State fish and wildlife agency(s).

Figure 7.4. **Karner blue butterfly**. The Karner blue butterfly (*Lycaeides melissa samuelis*), protected under the Endangered Species Act, occurs in open woods and pine and oak savannas in Indiana, Wisconsin, Michigan, Minnesota, New Hampshire, and New York. It is dependent on the wild lupine (*Lupinus perennis*). (Photo credit: Eunice Padley, Wisconsin Department of Natural Resources)

The National Park Service has a partial statutory planning requirement.

State Laws

All State forestry agencies have some enabling legislation that grants them broad authority over forestry-related activities in the State, thus enabling but not mandating periodic statewide planning and policy review. For example, the State of Delaware grants the State Forest Service jurisdiction over "all matters pertaining to forestry and woodlands within the State" (Delaware Code: Title 7, Chapter 29, subchapter 1). Administration of State-owned forest lands often resides with the State forestry agency but can partially or fully reside with wildlife, game management, public land, parks, and recreation agencies. For example, the New York Adirondack Park Agency manages 2.5 million acres of public land according to the State land master plan and regulates land use and development on 3.5 million acres of adjacent private land. Agencies that administer public land generally develop operational plans to guide management.

Statewide assessments and strategic plans are required of some State forestry agencies. For example, the Minnesota Forest Resource Act of 1987 requires an updated assessment of forest resources every 10 years and updates to the forest management program portion of the plan every 4 years. With passage of the Minnesota Sustainable Forest Resources Act (1995), the Minnesota Forest Resources Council directed the development of a vision and goals for the State forest resources. The State forestry agency planning then is completed with increased direction through this legislated body. The Maine Forest Service has a legislative mandate to report on significant forest policy issues and recommends actions on a biennial basis. New Hampshire must develop a comprehensive statewide forest resources assessment every 10 years followed by a plan that includes policies for future management and establishes legislative priorities (RSA 227–I).

Some States have adopted programs to assert State control over land development policies and undergo planning projects with impacts on forest sustainability. These programs attempt to reconcile the goal of environmental protection with that of urban and economic development. For example, the Maine Planning and Land Use Regulation Act (P.L. 1989, c. 104, Pt. A, §45 (new)) has identified a goal to "safeguard the State's agricultural and forest resources from development which threatens those resources." Growth management regulations guide and direct the pattern and pace of development.

Special Studies

Special studies can be authorized through legislative action and executive direction at all levels of government. Several Federal assessments with significance for non-Federal forests in the Northern United States were directly authorized by the Forest Stewardship Act of 1990. One was for the Northern Forest Lands of Maine, New Hampshire, Vermont, and New York; the other was for the New York-New Jersey Highlands Region. The act also authorized the establishment of a Presidential commission on State and private forestry to carry out a national study of non-Federal forest land management. The commission was never convened but the proposed study was contracted to the National Research Council (1998). All the above Federal laws and studies have written provisions to ensure coordination among relevant sectors.

Indicator 50. Provides opportunities for public participation in public policy and decisionmaking related to forests and public access to information

Public participation is a routine and integral part of land management and other activities of most natural resource management agencies. Public agencies often have decisionmaking authority regarding the resolution of natural resource conflicts. Traditional administrative mechanisms such as appointed boards, councils, commissions, formal notices of public meetings, and comment periods are often specified as the means to meet legal requirements for public involvement. Although the traditional mechanisms continue to be used, the present trend is to invite the public to participate in all steps of the decisionmaking process, from issue identification to assessment, planning, and the development of policy and management alternatives regardless of whether it is legally required. There is a positive trend to increase public access to information in both the public and private sectors.

Federal Agencies

Advisory committees may be established under the guidelines of the Federal Advisory Committee Act of 1972 to provide public input on Federal forest land issues, although this is not always invoked. The MUSYA, NEPA, NFMA, and FLPMA, mentioned previously with regard to planning, also specify the need to interact with the public as a part of national forest decisionmaking. National forests use a variety of mechanisms to address public issues, including preparing amendments to an existing forest plan, changing implementation of current plans, collecting information to inform discussion, and revising a forest plan every 10 to 15 years. The national forests in the Northern United States have prepared over 130 amendments to forest plans prepared under the NFMA to date (appendix 7–B). Amendments to the Shawnee and Hoosier National Forest plans were significant; most other amendments were limited in scope.

The Freedom of Information Act (1974) provides guidance to Federal agencies on their obligations to provide public access to information. This includes information on the organization, internal procedures, and information pertinent to official decisions.

The Cooperative Forestry Assistance Act of 1978 planning assistance program authorizes assistance to State Foresters or equivalent State officials to participate in natural resources planning at the State and Federal levels, and specifies the need for public involvement. Also, the Urban and Community Forestry Program and the Forest Stewardship Program both require State councils to provide advice on the most effective means to implement these programs. The Cooperative Forestry Assistance Act established a National Urban and Community Forestry Advisory Council with two positions specifically set aside for members of the public.

Extension activities are an important mechanism for bringing information to public attention. Most public agencies conduct some degree of extension activities; however, the USDA Cooperative State Research Extension and Education Service (CSREES) is the most widely known organization, with offices located in most counties across the country. The CSREES has a primary mission of public and professional education and has strong affiliations with State and county government, universities, consulting foresters, other Federal agencies, and other interested parties. Funding for the CSREES comes from the Renewable Resources Extension Act as amended in 1998, as Smith-Leaver Federal funds allocated by States, and as State matching funds and local funds.

State Agencies

State mandates on public involvement differ. For example, Massachusetts provides for an annual review of forest regulations by a committee of professionals (public and private) and landowners. The Maine Forest Service participates directly in the legislative process, as Maine law requires any substantive policy or regulatory changes to include involvement of stakeholders. The Wisconsin legislature requires the Department of Natural Resources to include the public in decisionmaking. Many States, such as New Hampshire and Vermont, use advisory and technical committees for policy review and for developing management options.

Most States involve the public at multiple levels of their organizations. For example, Delaware has a Governor's Forestry Advisory Council, a Community (urban) Forestry Council, and a Forest Stewardship Council. The District of Columbia works with the City Council, the Urban Forestry Council, and local government directly. Some States, such as Missouri, have used marketing research techniques such as focus groups to determine public opinion regarding forestry issues.

Nonprofit Organizations

Nonprofit organizations are often key in the public participation process. They may help to initiate, craft, or lobby for legislation or budgets or even facilitate discussion on key issues. Nonprofit organizations include professional groups such as the Society of American Foresters, the American Planners Association, the American Society of Landscape Architects, the American Fisheries Society, and the Wildlife Society. Other nonprofit organizations may focus on special interests or specific approaches to land management. These include organizations such as the National Wildlife Federation, the Wilderness Society, the American Woodland Owners Association, the Sierra Club, the Izaak Walton League, Ducks Unlimited, and the National Association of Conservation Districts.

Businesses

There is a trend for private businesses to be more open and accountable. Corporations are providing information and being accountable through various green certification initiatives, such as those sponsored by the American Forest and Paper Association's Sustainable Forestry Initiative and the Forest Stewardship Council. The desire for broad-scale planning to achieve sustainability goals has raised the question by businesses of the degree to which national antitrust laws and environmental goals conflict. Large corporations share information cautiously to avoid the appearance of adversely influencing prices or trade. The advent of readily available remote sensing information also increases the public's ability to monitor land management activities and to demand accountability from both public and private managers.

Indicator 51. Encourages best practice codes for forest management

Best practice codes are written guidelines that set standards for management activities. The codes may be regulatory, quasi-regulatory, or voluntary. A public institutional framework that supports best practice codes for forest management includes research that provides the scientific and technical basis for developing best management codes and for delivering technical and financial assistance to forest landowners (indicators 53 through 57, and 63 through 67). These services are usually provided through cooperative programs between Federal and State agencies. Forest industry and nonprofit organizations generally work with government programs to develop best practice codes and incorporate them into their operations.

Best Management Practices for Water Quality

One familiar best practice code prescribes the use of forestry best management practices (BMPs) to protect water quality. These guidelines came about because of the Clean Water Act

(1972) requirement that States develop programs to control nonpoint source pollution. The U.S. Environmental Protection Agency administers the act, and a partnership among Federal and State water quality and forestry agencies implements it. All of the Northern United States have BMPs available, generally on a voluntary basis; however, they are mandatory in Massachusetts on harvests greater than 25 cords. Likewise, the Coastal Zone Management Act of 1972 requires States to adopt forest management measures and enforcement procedures to protect coastal resources.

Public Lands

All public land management agencies develop management standards and guidelines for lands they manage as part of their mission. National forests are required by law to allocate lands among various uses suited to the site and to establish recommended standards and guidelines to ensure that desired future conditions of those lands can be achieved. Examples include silviculture guides, road and riparian buffer designs, wildlife habitat, growth models, and dynamic landscape simulations. By virtue of their inclusion in the National Forest Land and Resource Management Pan, they are enforceable.

Private Lands

Forestry on private lands is not directly regulated through Federal law; however, a number of States regulate forest practices, in general to control timber harvest practices and ensure adequate regeneration. Legislation in all of the Northern United States provides State forestry organizations with the mission to educate the public in sound forest management principles and practices, although in practice, outreach is often limited by available funding. Various State property tax abatement and incentive programs require the development and application of basic forestry management standards to determine landowner eligibility. States also develop special codes to protect native resources. For example, New Jersey has developed practices to regenerate Atlantic white cedar (*Chamaecyparis thyoides*).

Indicator 52. Provides for the management of forests to conserve special environmental, cultural, social, and/or scientific values

Many Federal, State, and local laws are intended to conserve and protect special environmental, cultural, social, or scientific values. Agencies may regulate against harm to special resources (e.g., soil, fisheries, water quality, watershed protection, air quality, threatened or endangered species). They may acquire or administer lands for special purposes, or provide technical assistance on how to mitigate the adverse impacts of forest management on special resources. State and Federal agencies have a responsibility to educate private landowners to recognize special areas and can encourage them to voluntarily manage these areas for special values.

Federal Designations

The Wilderness Act of 1964 (P.L. 88–577, 78 Stat. as amended; 16 U.S.C. 1131(note), 1131–1136) directed the Forest Service, the National Park Service, and the Fish and Wildlife Service to survey their roadless lands for possible wilderness designation. The act requires that wilderness areas be “administered for the use and enjoyment of the American people in

such a manner as will leave them unimpaired for future use and enjoyment as wilderness." Two other laws require wilderness reviews on national lands—the Federal Land Policy and Management Act of 1976 directed the Bureau of Land Management to inventory its roadless lands for wilderness protection, and the Alaska National Interest Lands Conservation Act (1980) also called for reviews of wilderness. There are 49 wilderness areas covering over 1.3 million acres in the Northern United States (appendix 7–C). Eleven of the Northern States have designated wilderness areas within their borders.

Designated by Congress, research natural areas (RNAs) are lands permanently protected for the purposes of maintaining biological diversity, conducting nonmanipulative research and monitoring, and fostering education. There are 41 RNAs covering 23,583 acres in the Northern United States (appendix 7–D).

The Federal Wild and Scenic Rivers and the American Heritage Rivers Programs provide opportunities to protect streamside forests and riparian functions. These designations cover public and private lands. In the Northern United States there are 39 Wild and Scenic River segments covering 1,803 miles of river and 8 nationally designated American Heritage Rivers (appendix 7–E).

National Forests

A variety of Federal legislation protects areas with unique cultural, social, environmental, or scientific values on national forests. Key legislation includes the following: the Wilderness Act of 1964, the Wild and Scenic Rivers Act (1968), the National Historic Preservation Act (1968), the Endangered Species Act of 1973, the Eastern Wilderness Act (1975), the Archaeological Resources Protection Act of 1979, the Federal Cave Resources Protection Act of 1988, the Native American Graves Protection and Repatriation Act (1990), the National Indian Forest Resources Management Act (1990), the Federal Land Policy and Management Act of 1994, and the Organic Administration Act (1897). These legislative mandates are incorporated into the management guidelines of the National Forest Land and Resource Management Plan.

States

States can have a variety of programs that use special area designations to conserve public values. For example, the Massachusetts Secretary of Environmental Affairs can designate privately and publicly owned land as an Area of Critical Environmental Concern based on the threat to public health, inappropriate uses, uniqueness of the area, and economic benefits of preservation. Under this designation, agricultural areas and groundwater recharge areas may be designated, as well as natural forested areas. Open space legislation is another vehicle States use to protect forests. Most State forest land management agencies allow areas to be set aside on State lands as part of an overall management program.

A number of States have led development of State systems of natural areas. The first State natural areas in the country were designated in Wisconsin in the 1950s. Wisconsin, Michigan, Missouri, and Maine now designate sites through administrative action. Sites in Illinois, Ohio, Indiana, Iowa, and Delaware are voted on by the State legislature. The number of forested acres in these State preserves is unknown. All 20 of the Northern United States

have natural heritage programs that inventory the status of plant and animal species and communities.

Private Initiatives

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).

Federal Threatened and Endangered Species

The Federal Endangered Species Act of 1973 was established to protect plant and animal species and their habitat. The Endangered Species Preservation Act of 1966 and the Endangered Species Conservation Act of 1969 were precursors to the Endangered Species Act. The U.S. Fish and Wildlife Service administers the law regarding inland species, and the Department of Commerce, through the National Marine Fisheries Service, administers marine species. All Federal agencies, including the USDA Forest Service, are responsible under section 7 of the Endangered Species Act to ensure that any action authorized, funded, or carried out by that agency is not likely to jeopardize the continued existence of any threatened or endangered species.

Indicators 53 through 57 refer to the extent to which the institutional framework supports the conservation and sustainable management of forests.

Sustainability is an overarching goal for a diverse array of public and private organizations, agencies, and individuals. There are many interconnections among agency, organization, and industry efforts to achieve sustainability on public and private lands, so it is difficult to definitively measure the effectiveness of any one effort. Each individual and organization has a role in conservation and sustainable management, although the motivations and ability to enact change will differ.

Forestry Agencies

Public forestry institutions administer public lands, implement programs and policies to protect and conserve public and private land resources, support research, and support public and professional education. Government seeks to influence natural resource management through education, technical assistance, financial incentives, tax incentives, and regulatory actions.

The USDA Forest Service and the State forestry agencies have the legislated responsibility to provide leadership in forestry-related issues. Federal and State agencies provide infrastructure for forestry technical assistance in the Northern United States. The USDA Forest Service provides service through State and Private Forestry, Research, and the national forest offices. There are 17 national forests and grasslands in the Northern United States. State forestry

agency organizations differ from State to State, but all have field offices in addition to the State offices. The Forest Service is one of several agencies in the U.S. Department of Agriculture. Likewise, State forestry programs are generally one division within a larger department of natural resources, conservation, protection, or agriculture. Differences among States include inter- and intra-departmental relationships relative to public versus private land management such as parks and recreation; regulation on insects and diseases, and pesticides; planning and enforcement of tax law; and other State environmental regulations.

Programs for Private Forest Land

A review of Federal programs for private forestry identified key challenges for Federal and Federal-State cooperative forestry programs, including the following (Sampson and DeCoster 1997):

- Help the most viable-size forest ownerships survive fragmenting pressure and remain productive for all forest functions.
- Retain forest functions in smaller tracts by marketing forest information and services to a broad range of landowners, including landowners of small tracts.
- Coordinate goals with taxing and regulatory systems so their polices reinforce forest maintenance goals.
- Cooperate with each other and the private sector through the marketplace so that success pays for more success and failure encourages correction.
- Educate the public on the benefits it receives from investing public money in improved management of private forest land.
- Provide credible data on the costs and benefits of various land use and management options so individuals and communities can make informed choices related to land-use planning, zoning, growth management, and sustainable development.

Green Certification

Probably the newest emerging institutions are those associated with green certification. Participation in green certification programs is voluntary. An organization's land management activity, as well as individual land or resource managers, may be certified. 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. Products from certified land may be identified by a special label. The label signifies that an accredited certification organization has conducted an on-the-ground evaluation of forest management and of the chain-of-custody of the timber through processing, to assure consumers that the products they are purchasing have come from responsibly managed forests. Green certification claims are verified on a first-party, second-party, or third-party basis.

	Green certification claims are verified on a first-party, second-party, or third-party basis.
Certifier	**Verification approach**
First-party	Internal assessment by an organization of its systems and practices
Second-party	Assessment by a customer or outside trade organization
Third-party accepted	On-site assessment by a neutral organization based on a set of standards

A variety of forest certification schemes are of interest (appendix 7–F). Potential incentives to participate in green certification programs include increased credibility of environmental claims used in product marketing, hopes for increased market share, and the ability to charge premium prices to underwrite sustainable management activity. The two widely discussed efforts are those of the Forest Stewardship Council (FSC) and the American Forest and Paper Association (AF&PA). The FSC, founded in 1993, is the umbrella organization for nonindustry, nongovernment third-party certification in the United States. This international organization accredits certifiers and facilitates the development of forest management standards for use by certifiers. The FSC has accredited two certifiers in the United States: Scientific Certification Systems and SmartWood. Several FSC regional working groups were established to tailor standards to local conditions. Three regional groups are active in the Northern United States: the Appalachian, Lake States, and Northeastern Working Groups.

The Northern United States has the most third-party certification nationwide. As of February 1, 2000, approximately 5.1 million acres (91 percent of the national acreage) was certified in the Northern United States. Pennsylvania has 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).

In addition, 93 companies and organizations (42 percent of national total) were 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 were five FSC certified forest managers in the Northern United States in 2000 (Hansen and Bratkovich 2000).

Associations

Long-standing, grassroots, nonprofit organizations are important institutions for helping to identify critical trends in forestry and provide a voice for their constituents in the broader forest policy dialogue. Professional, conservation, recreation, hunting, and landowner associations play an important role in public and professional education and technology transfer. Examples include the Society of American Foresters, the Ecological Society of America, Ducks Unlimited, and the National Woodland Owners Association.

Industry organizations such as the American Forest and Paper Association and the Technical Association of the Pulp and Paper Industry can have a long-term impact on forest sustainability. The AF&PA, the national trade association of the forest, paper, and wood products industry, embarked on its Sustainable Forestry Initiative in 1991. Members of AF&PA, generally primary and secondary manufacturers, must meet Sustainable Forestry Initiative principles and implementation guidelines as a condition of membership. Implementation guidelines apply to members' forests and to practices they use in procuring wood and fiber from loggers and other landowners. There are guidelines for public reporting and goals regarding their relationship to private and public land in the United States (AF&PA 1994). Members of AF&PA may or may not own land.

Land Trusts

Local, regional, and national land trusts are nonprofit organizations that protect land for specific purposes by acquiring land or conservation easements on a willing buyer and willing seller basis. Many reconvey that land to a government agency or another nonprofit organization. In 1998 there were approximately 831 local and regional land trusts operating in the Northern United States—an increase of 278 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. Some of the oldest trusts in the Nation operate within the Northern United States, including the Society for the Protection of New Hampshire Forests, which was instrumental in passing the Federal Weeks Acts.

Institutional Investors

Another trend is an increase in forest landownership by institutional investors such as pension funds, insurance companies, banks, endowments, and foundations. This trend may have positive implications for forest sustainability (Binkley and others 1996). These institutions often have the capital to invest in forest land and management, and the ability to retain capital over the decades it takes to realize profit from forestry investments.

Forest Industry

Of the various forest industries in the Northern United States, paper companies are the most prominent institutions in the for-profit sector. Industry manages land, procures stock from their own lands, and works to ensure a continuing supply of resources from local, regional, and even global markets.

Indicator 53. Provide for public involvement activities and public education, awareness and extension programs, and make available forest-related information

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 recent burgeoning of information available on the Internet

has made forestry information more accessible to the average citizen. The quality of the information being provided is a concern. Many public agencies, including the USDA Forest Service and State forestry agencies, view one of their critical roles as providing credible, unbiased information for use by any citizen or stakeholder group.

Public Involvement

Public involvement activities are characterized by dialog in which all affected stakeholders have an opportunity to influence decisions that affect them. Most public institutions have mechanisms in place to engage the public and do so with varying degrees of success. The number and rights of stakeholders differ, however, depending on whether the decisions concern private or public landholdings. Regardless of landownership, citizens who are well informed and knowledgeable about forestry issues and activities are in the best position to participate in decisionmaking.

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 with experience in facilitating resolution of conflicting values and objectives among stakeholders. Other barriers include inconvenient or inaccessible meeting locations, lack of multilingual outreach and awareness efforts that result in gaps in stakeholder representation, delays between decisions and actions that discourage prolonged involvement, and resentments held by individuals or groups owing to past government activity.

Outreach

Existing Federal, State, and private forestry outreach programs often target individuals who own forest land or are involved in some aspect of forest management planning or harvesting. Improved land and resource management and increased compliance with current laws and regulations are general objectives of outreach efforts. For example, it is estimated that nationally, outreach regarding BMP implementation has reached 95 percent of loggers, and BMP compliance may be over 90 percent based on independent inspections of State forestry departments (USDA Forest Service 1997a).

Public education and program delivery directly to forest landowners is complicated in the Northern United States by an increasing number of individuals who own small parcels of forest land (Birch 1996a). National estimates are that these services may reach approximately 5 percent of landowners with the potential to affect 15 to 20 percent of nonindustrial private forest land (USDA Forest Service 1997a). There were an estimated 3.9 million private forest land ownerships in the Northern United States in 1994 (Birch 1996a).

Private Landowners

Private forest landowners as a group are diverse in legal organization, economic circumstance, and management experience. In 1994, about 94 percent of the private owners were individuals. Individuals held 71 percent of the private forest land, corporations held 20 percent, and the remaining 9 percent was held by partnerships, undivided estates, clubs, associations, and Indian tribes (figure 7.5). Sport and recreation clubs are common

components of ownership in Pennsylvania, New York, and Michigan. Undivided estates are important in Maine and West Virginia. Indian tribes are prominent ownership groups in Maine, Michigan, Minnesota, and Wisconsin.

White-collar workers and retirees each account for more than 30 percent of the individual private forest landowners in the Northern United States, and collectively they own over half of the forest land acreage. The number of forest landowners described as white-collar workers declined and the number of retirees increased between 1978 and 1994. In 1994, farmers accounted for 9 percent of the forest landowners and held 16 percent of the forest land. For this reason, many traditional technical assistance and cost-share programs target farmers. The number of forest landowners described as blue-collar workers decreased during the same period, and the number of owners with other occupations increased (figure 7.6).

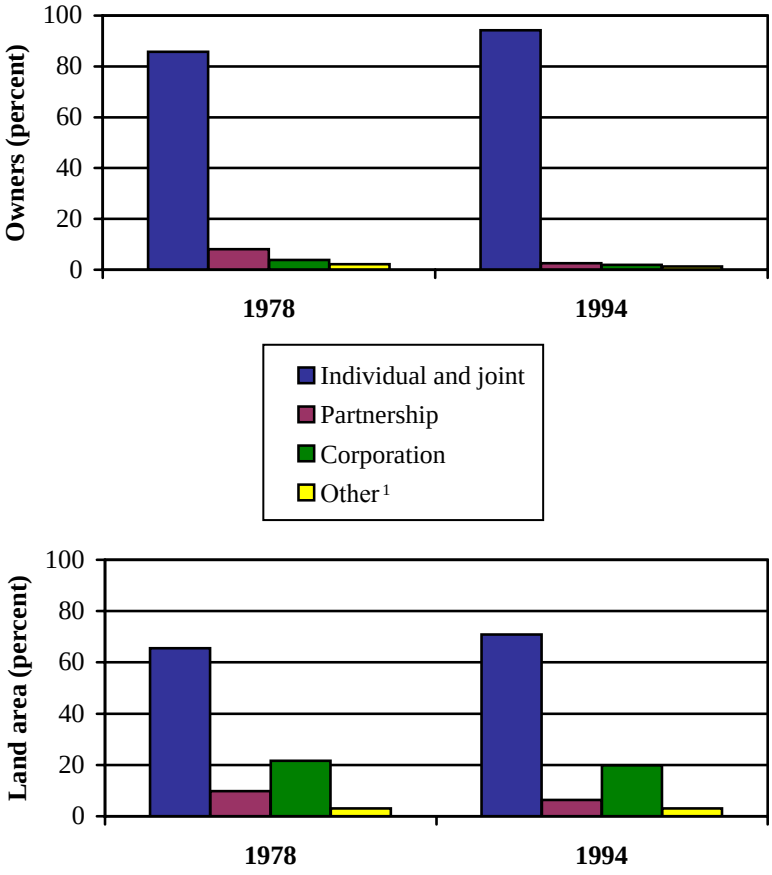

Figure 7.5. **Trends in distribution of private ownerships, by form of ownership, in the Northern United States** (Birch 1996a). Landowner surveys were conducted in 1978 and 1994. The form of ownership in each year is shown as a percentage of the total number of owners (above) and the total land area owned (below).

[1]Includes sport and recreation clubs, undivided estates, associations, and Indian tribes.

People own land for a variety of reasons. Nearly 42 percent of the private forest landowners in the Northern United States own forest land as part of their farm or residence. Roughly 10 percent cited farm or domestic use as the most important reason for holding forest land. Recreation and aesthetic enjoyment is the primary benefit to 29 percent of owners who collectively hold 26 percent of private forest land acres. Land investment continues to be important. Only 1 percent of private forest landowners say their land is primarily for timber production, but they control 19 percent of private forest land, making acreage devoted to timber production the most extensive. Nationwide, nonindustrial private forest lands are producing half of the country's domestic timber supply. An estimated 49 percent of private owners have harvesting experience; they control 75 percent of the private forest land (Sampson and DeCoster 1997).

Landowner Assistance Programs

There are a variety of Federal technical assistance and incentive programs available to private forest landowners (table 7.3); however, many landowners are not aware of the resources available to them. Forest Service programs affecting private lands are implemented cooperatively with State forestry agencies designated in authorizing legislation. The USDA Natural Resources Conservation Service works closely with county Soil and Water Conservation Districts. The U.S. Fish and Wildlife Service works with State fish and wildlife agencies.

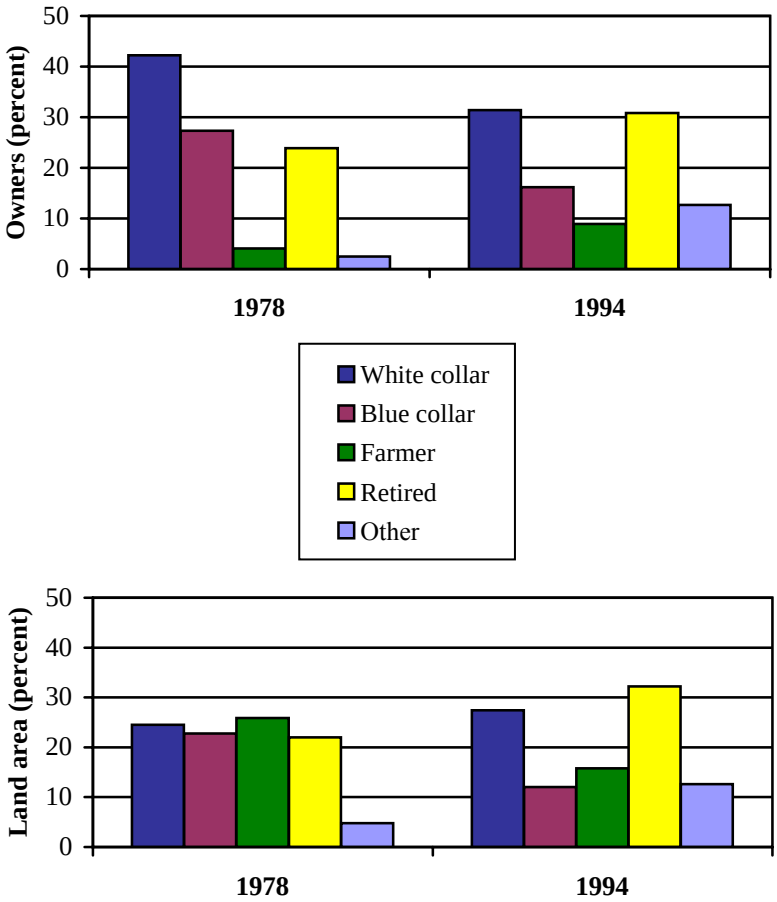

Figure 7.6. **Trends in distribution of private ownerships, by occupation, in the Northern United States** (Birch 1996a). Landowner surveys were conducted in 1978 and 1994. The ownership by occupation in each year is shown as a percentage of the total number of owners (above) and the total land area owned (below).

States, counties, and cities may also provide incentives to landowners. For example, the New York Department of Environmental Protection provides cost-share incentives for forest landowners who may affect water quality in reservoirs that supply drinking water to New York City. In most cases, requests for technical and financial assistance are directed toward government resources. There is continuing public debate over the effectiveness of incentive programs in achieving desired outcomes, and consultants who desire to provide similar services for a fee believe free government assistance undermines their ability to succeed in the marketplace.

Community, Statewide, and Municipal Programs

One of the basic tenets of an ecosystem-based approach to management is to look at planned activities in the broad social, economic, and environmental context because overarching conditions can impact the viability of individual land management and investment strategies. Various Federal programs exist to provide this type of information in support of State and community efforts to conserve or protect resources critical to public health, safety, or welfare (table 7.4).

Table 7.3. **Examples of Federal technical assistance and financial incentive programs available to forest landowners**.

Agency[1]	Program	Description
USFS	Forest Stewardship	Education and technical assistance. Focuses on management of nonindustrial private forest land; encourages preparation of land management plans for multiple uses.
USFS	Forest Land Enhancement	Replaced the Stewardship Incentive and Forestry Incentives Programs in FY 2003. Technical assistance and cost sharing. Focuses on management plan development and cost-share activities on nonindustrial private forest land.
NRCS	Environmental Quality Incentives	Technical assistance and cost sharing. Develops and implements management plans to protect and conserve soil, water, and related resources.
USFWS	Partners for Fish and Wildlife	Technical assistance to restore and conserve wildlife habitat.
NRCS	Conservation Reserve	Technical assistance, cost sharing, land rent. Converts unsuitable cropland to permanent vegetative cover.
NRCS USFS	Public Law–566 Small Watershed Incentives Program	Technical assistance, cost sharing. Focuses on protecting water quality. Assists communities in developing watershed management plans on watersheds less than 250,000 acres.
NRCS	Conservation Technical Assistance	Technical assistance. Focuses on land management plans primarily for farm-forest owners.
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	Financial incentives to develop fish and wildlife habitat on private lands.
NRCS	Wetlands Reserve	Wetland protection through easements and total coverage of wetland restoration costs.

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

In a review of public programs and options for private forestry, Sampson and DeCoster (1997) point out that Federal private forestry programs are not keeping pace with the changing demographics of the country. They recommend expanding service to rapidly developing communities and suggest more sophisticated marketing to target 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 reluctance to invest in marketing by policy leaders was cited as the major impediment to adopting these changes.

Environmental Education Network

The institutional framework for environmental education comprises a plethora of interrelated national agencies, organizations, and programs that provide organizational, financial, and technical assistance to government and private efforts at State and local levels.

Table 7.4. **Examples of Federal assistance programs operating at community, State, or regional scales**.

Agency[1]	Program	Description
USFS	Cooperative Forest Health Management	Provides technical expertise to detect, evaluate, and monitor forest health in rural and urban areas and to suppress or eradicate forest insects and disease.
USFS	Economic Action	Strengthens community economic conditions through programs such as Rural Development and Wood in Transportation.
USFS	Fire Management	Develops State programs to protect lives, property, and natural resources from uncontrolled wildfires.
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	Forest Legacy	Protects forest lands threatened with conversion to nonforest uses by purchasing conservation easements or fee titles from willing private landowners.
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.

[1]NRCS = USDA Natural Resources Conservation Service
USFS = USDA Forest Service

Through the National Environmental Education Act (1990), Congress established the U.S. Environmental Protection Agency's Environmental Education Office to administer federally funded grants. That same year, Congress authorized the National Environmental Education Training Foundation (NEETF), a private nonprofit organization that strives to connect environmental learning to progress on issues of national concern. The NEETF is best known for its continuation of the annual Times Mirror/Roper survey of Americans' environmental knowledge and viewpoints referred to as the National Report Card (NEETF 1998). A National Environmental Education Advance Project provides resources and networking opportunities for member States to build environmental education capacity at the national, State, and local levels.

Many agencies and organizations belong to the North American Association for Environmental Education, which focuses on information dissemination, education reform, and innovation through training and expansion of partnerships.

Forest health and forestry issues are usually only one component of a variety of environmental education themes. A joint USDA Forest Service and National Association of State Foresters conservation education program targets youth, urban communities, and national forest and State forest visitors. The program strives to connect people to the land. It provides the tools they need to take informed actions related to sustaining natural and cultural resources and fostering understanding of the interrelationship in natural systems and between people and the land.

Programs targeting school-aged children are popular. For example, the Grand Rapids School Forest Demonstration Center is a 195-acre property used for educational purposes. A high school curriculum was developed to cover forest history, tree identification, forest measurements, cultural practices, wildlife, and forest health protection. This curriculum has been distributed to about 100 school forests located throughout the State of Minnesota. The property, inventoried by students with help from the local soil and water conservation district, is also used to demonstrate best management practices and to conduct educational programs for the general public and professionals (Heyer 2000) (figure 7.7).

Figure 7.7. **Grand Rapids School Forest Demonstration Center**. This 195-acre property is used for a range of educational purposes. (Photos courtesy of Grand Rapids High School)

Many people believe environmental education should be integrated within the overall educational program of America's children and focus on local ecosystems. Project Learning Tree and Project Wild are two of the most popular programs within the forestry community that target teachers and school children. Yet nationally, less than 3 percent of teachers are involved with these programs (USDA Forest Service 1997a). Another popular program is the Envirothon, a competition among high school students that focuses on a different environmental theme each year.

Private Efforts

Private organizations sponsor public education and outreach to citizens and landowners; some also provide technical training for foresters and loggers. Many varied organizations such as the Audubon Society, the Wilderness Society, the National Woodland Owners Association, and American Forests publish magazines and devote resources to public information and education. The Izaak Walton League has a Sustainability Education project. The AF&PA's Sustainable Forestry Initiative program provides information to landowners through member companies, loggers, and foresters.

Indicator 54. Undertake and implement periodic forest-related planning, assessment, and policy review including cross-sectoral planning and coordination

The planning process helps to identify resource and management needs and opportunities, and helps decisionmakers set 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.

The Forest Service develops national strategic direction, and major Forest Service units in the Northern United States (National Forest System, Northeastern Area State and Private Forestry, and Northeastern and North Central Research Stations) develop regional strategic plans linked to this national direction. The Northeastern Area State and Private Forestry develops a new strategic plan in cooperation with the Northeastern Area Association of State Foresters every 5 years. Individual research work units realign their work priorities every 5 years.

Nearly all 20 of the Northern United States have active State forestry advisory committees that coordinate statewide activities among sectors of the forestry community (NASF 1996). The Forest Service and the States support planning in the Northern United States through cooperative programs such as State Forest Resource Planning, public laws (Small Watershed Program), and Urban and Community Forestry (table 7.5).

Table 7.5. **Examples of Federal planning programs**.

Agency[1]	Program	Description
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.
NRCS USFS	Public Law–566 Small Watershed Incentives Program	Technical assistance, cost sharing. Focuses on protecting water quality. Assists communities in developing watershed management plans on watersheds less than 250,000 acres.
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.

[1]NRCS = USDA Natural Resources Conservation Service
USFS = USDA Forest Service

National Forest Planning

The Forest Service and other Federal land management agencies must revise their forest plans periodically. Plans for national forests in the Northern United States were written 10 to 15 years ago and are in the process of revision. Plans are revised as public expectations for the national forests change and as new scientific information becomes available for

management designations and standards. National forest planning rules now being developed are intended to make adapting to ongoing change easier than it has been. Some changes are dealt with between planning periods through amendments to existing plans. To date, over 130 amendments to national forest plans have been prepared in the Northern United States (Monson 1998).

State and Local Planning and Assessment

Lands owned by States, counties, and other public entities are not under the same mandates as national forests. No comprehensive assessment of the development and implementation of management plans for these lands has been attempted across the Northern United States. Some land is being assessed through green certification of public lands, as mentioned earlier in this chapter. State lands in Pennsylvania, Minnesota, Massachusetts, and New York have been certified, as well as county-owned land in Minnesota.

Some State forestry agencies develop long-range plans under the strategic guidance of broader departmental plans, as in Illinois, Rhode Island, and Missouri. In Illinois, State forest resource plans are tied to the strategic plan for the Illinois Department of Conservation, which includes fisheries, wildlife, natural areas, and the Division of Forestry. In Missouri, the Department of Conservation, which includes the State forestry agency, revises its strategic plan every 5 years.

Urban and rural residents alike depend on natural resources, yet current policies do not make those connections evident. In many urban areas, health, welfare, and education needs are higher priorities for State and local governments and community action groups than are environmental issues. Environmental issues with high priority in urban areas include land restoration, remediation, and wetland mitigation. Rural education and planning efforts focus on individual land stewardship and contributions to water quality.

State natural resource agencies often provide technical assistance to regional, county, and local land use planning activities.

Landowner Management Plans

Development and implementation of management plans for private nonindustrial lands are perhaps the greatest challenge to achieving forest sustainability. Birch (1996a) estimated that only 5 percent of private forest landowners, who control 29 percent of the private acreage, have a written management plan. Of private acreage with plans, roughly one-third is owned by the forest industry and two-thirds are owned by more than 205,500 nonindustrial private forest owners. A primary goal of the Federal Forest Stewardship Program is to increase the amount of nonindustrial private land that has a written management plan.

Nearly 18 percent of nonindustrial private forest landowners, who control 16 percent of the area covered by written plans, prepare written plans themselves. An estimated 13 percent of the nonindustrial private forest landowners' plans were prepared by consultants, accounting for 35 percent of the forest land covered by written plans. State service foresters and wildlife biologists wrote 37 percent of their plans, covering 27 percent of the acreage. Industrial foresters prepared 3 percent of the written plans for this group, covering an estimated 8 percent. The USDA Natural Resources Conservation Service, USDI Bureau of Indian Affairs,

and USDA Cooperative State Research Extension and Education Service prepared the remaining 28 percent of the plans that cover the remaining 25 percent of the forest under a management plan.

Assessments

Assessments address issues or concerns about land use and provide background data and information that is useful for calculating the risks associated with decisions and for policymaking. Changes in ecological conditions may trigger the need for an assessment.

Assessments can be conducted at a variety of scales. Watershed and ecoregional assessments often cover multiple States. Statewide assessments generally are precursors to State land and resource planning. In the Northern United States, multistate assessments have been conducted in the Mid-Atlantic Highlands, the Great Lakes States, the Northern Forest Lands of northern New England and New York State, the Ozark Ouachita region in Missouri and Arkansas, and the Chesapeake Bay watershed.

States may conduct assessments to address specific forest-related issues as well as to support comprehensive planning. For example, Massachusetts updated its 1980 generic environmental impact report in 1992 to address regulations in the Forest Cutting Permit program and the forestry program on State lands (Soper 1992). A committee of public and private professionals and landowners reviews these regulations annually. Minnesota prepared a generic environmental impact statement that examined the impacts of timber harvesting on the State's environment and economy.

An increasingly important component of planning and policy development is the ability of organizations to compile, analyze, and graphically display data for public review. Federal and State governments and universities are often collaborators in developing and warehousing public information. Capacity building in this area is a common component of most government and private sector organizational development.

Policy Review

Public policy is always subject to public review and scientific scrutiny. As policy decisions are implemented within organizations, the link between actual and desired effects become clear. A variety of public and private initiatives contribute to policy review. Two such reports include the National Research Council (1998) report *Forested Landscapes in Perspective: Prospects and Opportunities for Sustainable Management of America's Nonfederal Forests* and the USDA Committee of Scientists (1999) report *Sustaining the People's Lands, Recommendations for Stewardship of the National Forests and Grasslands into the Next Century*. Together these reports present a comprehensive assessment of current efforts to implement Federal forest policy (table 7.6).

Table 7.6. **Recommendations from National Research Council (1998) and the USDA Committee of Scientists (1999)**.

***Forested Landscapes in Perspective* (National Research Council)**
• Ensure the long-term integrity of forest ecosystems that compose the nation's non-Federal forests, actively addressing conditions that diminish their ability to contribute to the well-being of the Nation's citizens.
• Improve the ability of the Federal government to focus on the national interest in non-Federal forests, especially the ability to identify national interests in non-Federal forests and deliver programs and support that will enable accomplishment of these national interests.
• Coordinate and suitably strengthen incentive, technical-assistance, and regulatory programs for non-Federal forests, and broaden their application to a wider variety of individual and societal interests.
• Promote public and private investments in non-Federal forests by establishing innovative investment policies and fostering healthy national and regional economies. Investment should be broadly construed to include financial, intellectual, human, and ecological resources.
• Improve the quantity, quality, and timeliness of information about non-Federal forests, and enhance access to this information.
• Acknowledge public and private rights and responsibilities associated with non-Federal private forests and the multitude of ways that these rights and responsibilities are exercised by various landowners.
• Exercise Federal leadership, counsel, and as appropriate, resources to sustain positive contributions from U.S. non-Federal forests to the world.
***Sustaining the People's Lands* (USDA Committee of Scientists)**
• Make sustainability the overarching objective of national forest stewardship.
• Ecological sustainability is a necessary foundation for stewardship.
• National forests contribute to economic and social sustainability and the well-being of people.
• Consider the broader geographic, political, economic, and social landscape surrounding the national forests and grasslands to understand their role in achieving sustainability.
• Build stewardship capacity for sustainability internally and externally, and use a collaborative approach to planning.
• Make decisions at the spatial scale of the issue or problem and use assessments at a variety of scales to provide a credible foundation of information.
• Make effective use of scientific and technical analysis and review, and make review and evaluation processes ongoing elements of stewardship.
• Integrate budget realities into planning.
• Watersheds and timber supply are central to management purposes on the national forests and should be integrated into desired future conditions during planning.
• Recognize that external influences affect the success of collaborative planning and stewardship efforts.

Indicator 55. Develop and maintain human resource skills across relevant disciplines

Skills Needed

Forest ecosystems are complex and intermingled in a broader context with other landscapes, water, people, and communities. This complexity requires integration of a broad range of skills and disciplines to adequately address the goals of sustainable forestry, now and in the future. Periodic assessment of existing skills compared with emerging issues, technology capabilities, and legal mandates, facilitates natural resource managers' ability to respond to change and to anticipate needs.

Traditional natural resource skills and expertise in forestry, wildlife biology, soil science, hydrology, botany, archaeology, and ecology provide a foundation for forestry decisionmaking, particularly within Federal, State, and local public land management agencies. Increasingly, over the past two decades, skills in the social sciences, law and policy, land use planning, marketing, education and communication, and conflict resolution have also become critical, as landownership patterns have changed, public awareness and access to information and interest in the environment have grown, and the importance of forest resources in the urban environment is understood and appreciated. Increased public outreach and more sophisticated marketing approaches are recommended to increase the relevance and effectiveness of organizations working toward sustainability (Sampson and DeCoster 1997).

Significant strides in analytical capabilities have been made in recent years. Analysis and information technology skills and expertise are required to take advantage of leading-edge technology (such as global positioning system [GPS], geographic information system [GIS], and database use and development), improving integration of all resource considerations in land management and program delivery. State-of-the-art forest product utilization and manufacturing represent another arena of specialized skills needed to ensure sustainable development.

Budgets

Increased emphasis on organization effectiveness and efficiency, results and accountability, and budget constraints lead to scrutiny of skills available and current business practices. Computerization has changed the way we do business throughout the public and private sectors, necessitating computer-skill development for all employees. Fiscal integrity and organizational efficiency place pressure on existing employees to assume expanded or new responsibilities, which, in turn, increases the need for skill development and retraining.

Employment

This section examines three levels of public natural resource management—Federal (USDA Forest Service), State forestry agencies, and local or county-level conservation districts, private sector consultants, and industry.

Nationally, in September 2002, the Forest Service employed approximately 30,000 employees, excluding summer employees, down from about 40,000 in 1999. The agency workforce includes just over 3,000 permanent employees in the Northern United States, including employees of the Eastern Region National Forests, the Northeastern and North Central Research Stations, the Forest Products Laboratory, and the Northeastern Area of State and Private Forestry (USDA Forest Service 2002).

Agency-wide statistics for staff employed under the general schedule as of June 30, 2002 (USDA Forest Service 2002) were:

- Average age—45.5 years
- Average grade—GS–9
- Average time in service—17.4 years

The State forestry agencies manage State-owned forest lands and implement a host of State and Federal programs designed to assist private forest landowners, provide rural fire protection, and coordinate and assist city and community leaders with urban forestry programs.

The 20 State forestry agencies of the Northern United States, and the District of Columbia, employed a total of just over 3,140 permanent employees in 1998 (NASF 1998) and 1,900 seasonal or temporary employees the same year. Their staff sizes are commensurate with the amount of forest land in the State and the complexity of issues and programs. Wisconsin, Minnesota, Pennsylvania, and New York each have permanent workforces totaling over 340 employees, with Minnesota the high at 400 (figure 7.8). At the other end of the spectrum, Connecticut and Rhode Island each have 31 permanent employees, and Delaware and the District of Columbia are low at 24 employees each.

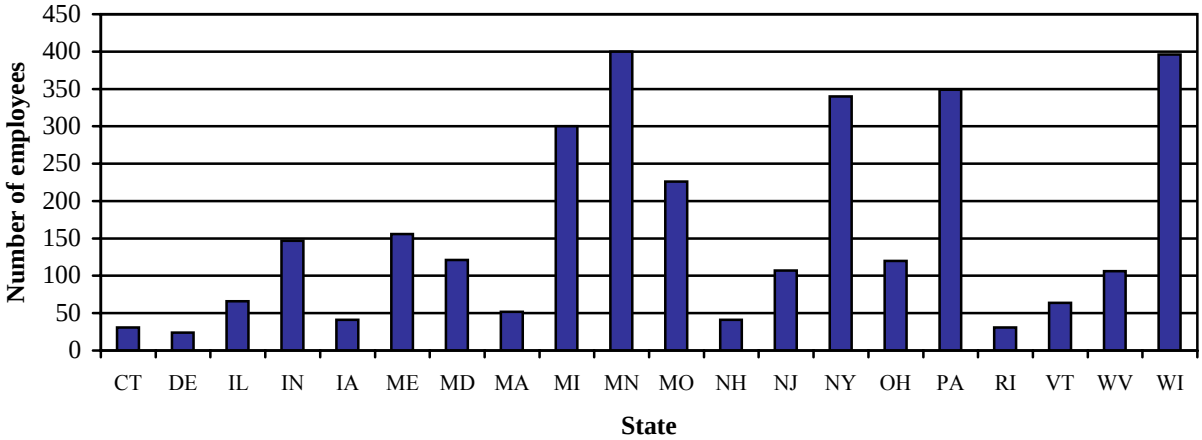

Figure 7.8. **Employment by State forestry agencies**. In 1996, State forestry agencies in the Northern United States employed roughly 3,400 individuals in permanent managerial, professional, technical, and clerical positions. The largest State forestry agencies are in Minnesota, New York, Pennsylvania, and Wisconsin (NASF 1998).

Several State forestry agencies face a challenge of retaining experienced field foresters and managers owing to State salary structures and caps. State forestry agencies are excellent first employers, providing training, broad experience, benefits, and opportunity. However, many service foresters are lured to forest industry or into private consultation practices, where salary potential is often much greater.

Across the United States, nearly 3,000 conservation districts—almost one in every county—are helping local people to conserve land, water, forests, wildlife, and related natural resources.

Known in various parts of the country as soil and water conservation districts, resource conservation districts, natural resource districts, land conservation committees, and similar names, they share a single mission: to coordinate assistance from all available sources—public and private, local, State and Federal—in an effort to develop locally driven solutions to natural resource concerns.

More than 15,000 volunteers serve in elected or appointed positions on conservation districts' governing boards. They work directly with more than 2.3 million cooperating land managers nationwide, and their efforts touch more than 778 million acres of private land.

Among other things, conservation districts help:

- Implement farm conservation practices to keep soil in the fields and out of waterways.
- Conserve and restore wetlands, which purify water and provide habitat for birds, fish, and numerous other animals.
- Protect groundwater resources.
- Plant trees and other land cover to hold soil in place, clean the air, provide cover for wildlife, and beautify neighborhoods.
- Help developers and homeowners manage the land in an environmentally sensitive manner.
- Reach out to communities and schools to teach the value of natural resources and encourage conservation efforts (http://www.nacdnet.org/about/aboutcds.htm).

There are 984 county conservation districts in the Northern United States. Out of 755 conservation districts responding to a survey in 1998–1999, 88 reported having a forester on staff and 23 employ forestry technicians (Kershner 2000). However, 207 districts mentioned that other conservation district staff worked on forestry issues.

Skill Pool and Development

Maintaining skill pool proficiency is an ongoing endeavor throughout an employee's career. Initial skill development is most often undertaken at a university or other post-secondary educational institution. Beyond the initial acquisition of skills, several means of maintaining skills exist, including licensing, certification, and registration. In each case, continuing education is an integral part of the effort. Each professional field (engineers, foresters, certified public accountants, wildlife biologists, etc.) has its own requirements for ensuring proficiency and state-of-the-art capabilities and skills within the discipline through time.

University Training and Accreditation

Land grant universities are present in each of the 20 Northern States. These institutions provide training in a variety of disciplines needed for sustainable land management. State colleges and forestry agencies are closely affiliated with the USDA Cooperative State Research Extension and Education Service. In the Northern United States between 1990 and 1996, enrollment declined at public 4-year colleges and institutions. This decline is projected to continue because of decreases in residents between the ages of 18 and 24 years (AASCU and NASULGC 1998).

Students with a variety of degrees are employed by public land management agencies or the private sector to assist in sustainable forest management, as identified above. Most students receive undergraduate degrees in natural resource management, social or political science, computer and information technology, business and accounting, communication, or

education. An increasing number of employees have postgraduate degrees (master's or Ph.D.) in their area of expertise. It is important to recognize that prospective employees are trained in a variety of programs offered at universities (Goecker and others 2000).

Forestry degrees are received only from accredited schools. Colleges and universities receive accreditation from the Society of American Foresters (SAF), a professional organization. The SAF periodically audits the professional degree programs of forestry colleges and universities, and reviews technical forestry education programs. The SAF accredited 20 schools with professional forestry degree programs in the Northern United States in 1996, and recognized 11 technical forestry education programs. The SAF also has a continuing education certification program for forestry professionals.

Licensing, Registration, and Certification

Standards of professional performance are often set in licensing, registration, and certification programs. Eight of the Northern United States and some private organizations administer these types of programs (table 7.7).

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 attesting that a person has attained a certain level of competence that is usually performed by a peer group. The Society of American Foresters and the Association of Consulting Foresters are examples of private forester certification programs.

Table 7.7. **Forester registration and licensing programs**. Eight of the Northern United States have forester registration, licensing, or certification 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]Mandatory certification is included in statute.

A bachelor of science in forestry and forestry experience are common components of State requirements, although Connecticut instead requires successful completion of an exam. Continuing education is part of the State programs, except in West Virginia. Rhode Island's licensing program, developed in 1928, was the first in the Nation. The Society of American Foresters also has a national certification program.

The Association of Consulting Foresters of America has membership requirements similar to those for registered, licensed, or certified foresters. Members must have graduated with a degree, have 5 years or more experience in professional practice, and serve as a consultant to

the general public on a fee basis. Of 540 members nationwide, 105 operated in the Northern United States in 1999 (Association of Consulting Foresters of America, Inc. 1999).

Other natural resources professionals involved in managing the Nation's forests also have registration, licensing, and certification programs with formal education, experience, and continuing education requirements. For example, the Wildlife Society has a certification program for wildlife biologists with a mandatory renewal every 5 years. The American Planning Association certifies practitioners through the American Institute of Certified Planners, and audits and accredits college planning curricula in a manner similar to the Society of American Foresters.

Education

Most private corporations and government agencies involved with forest management offer or require some type of professional development or in-service training program for their employees. One innovation of the Forest Service is the Eastern and Southern Regions University (ESRU). The university offers approximately 90 courses based on training needs identified in employees' individual development plans. It is an opportunity to get a variety of functional training in one 2-week period, at one location, and for one tuition charge. It offers supervisory and required training sessions at a time least likely to interfere with field operations.

Trade associations such as the AF&PA provide member companies with new information and sponsor or cosponsor training programs for loggers, sawyers, and procurement foresters. The AF&PA's Sustainable Forestry Initiative (SFI) has a system of State committees set up to promote SFI principles. Nationally, as of the year 2000 and since the AF&PA program began, 44,000 loggers and foresters have completed comprehensive training programs in sustainable forestry practices, with another 33,000 having partially completed training (AF&PA 2000).

Public landowner outreach and assistance programs provide vehicles for developing skills in the private sector and among lay individuals who may manage their own land and natural resources. Landowner associations, such as State and national woodland owners associations, provide workshops and field visits to maintain communication and educational opportunities for interested forest landowners. University extension services and USDA Forest Service continuing education and conservation education for landowners are also available in all States served by the Northeastern Area State and Private Forestry.

Indicator 56. Develop and maintain efficient physical infrastructure to facilitate the supply of forest products and services and support forest management

Efficiency with respect to physical infrastructure means allocating resources, without waste, to produce desired outputs, including wood and minerals for manufacturing, opportunities for recreation, viewing wildlife, enjoying scenery, providing clean air and water, and dispersing or storing by-products of economic activity.

Developing Infrastructure

Conflicting opinions on the highest and best use of public and private forest land affect opinions on the efficiency of the supporting physical infrastructure that can include roads,

campgrounds, ski lifts, tree nurseries, fish nurseries, airports, research stations, and sawmills. This conflict is exacerbated by the fact that the diversity and intensity of demands for goods and services is increasing, yet the forest land base is finite. The costs and benefits associated with building and maintaining permanent structures vary according to the biophysical properties of an ecosystem and various social, economic, and demographic factors, such as proximity to major population centers and tolerance among competing interests.

The current debate over the amount of roaded and roadless areas to maintain on national forest land is a prime example of these difficulties. Roads facilitate hauling timber, provide access for recreation, and are used for firefighting and forest inventory and monitoring. They also are avenues for invasion of exotic species and, in specific locations or in high densities, interfere with the habits of some animals and detract from the wilderness experience desired by a segment of the population. Disagreement exists over the fair allocation of costs and benefits of roads among public and private parties.

Other examples include the infrastructure issues that communities grapple with to achieve a ratio of developed to undeveloped lands to guarantee a high-quality living environment for urban and suburban dwellers. This includes gray infrastructure, such as the networks of roads, sewers, electricity, gas, and communication lines; and green infrastructure, such as open spaces that can be used to filter pollutants, protect lake shores and streambanks, reduce flooding, decrease urban heat island effects, maintain community aesthetic attributes, and provide recreational opportunities.

Maintaining Infrastructure

Beyond the amount of infrastructure to develop, there is the question of maintenance of existing infrastructure. Clearly on public lands, it is well documented 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 the wild land forest resource. In more developed areas, community organizations and agencies are compiling inventories of restoration needs. These include restoration of wetlands, shorelines, floodplains, various vegetative communities, and terrestrial and aquatic habitats, and reclamation of various brownfields (areas contaminated by toxic materials) and gravel pits to provide environmental services and amenities.

Industry Infrastructure

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 among environmental, social, and economic factors. Manufacturing capacity must be balanced with forest growth and harvest potential, industry profitability, and community stability. Key considerations in determining 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. New harvest technology and development of composite wood products has increased utilization of raw materials and smaller diameter trees. Progress in utilization can be made by modernizing traditional sawmill operations across the Northern United States. More secondary processing facilities are desired across the Northern United States.

Indicator 57. Enforce laws, regulations, and guidelines

The types of laws that directly or indirectly regulate natural resource management generally belong to a number of categories. There are laws to protect the environment (air quality, water quality, species preservation, soil conservation), protect public property, provide tree protection, and protect special features (i.e., sensitive or fragile areas containing unique environmental attributes or resources). Both government and nongovernment organizations bring institutional capabilities to bear in implementing laws, regulations, and guidelines on public and private lands. Legislation affecting forestry has been forged in an ongoing process responding to the increasing knowledge of forestry and related disciplines, and formed to address environmental and social problems apparent at the time. A common complaint is that legislation and implementing regulations are often complex, confusing, and establish conflicting goals or procedures for implementation. Enforcement under these conditions is difficult.

National Laws

The USDA Forest Service is a nonregulatory agency; therefore, its primary role is to provide technical expertise in the development of and education about laws, regulations, and guidelines. Laws affecting the national forests have most recently been under intense scrutiny. A committee of scientists was appointed to study potential redrafting of the planning regulations for the agency. That effort indicated that a clear statement of National Forest System policy is needed.

Forest Service cooperative programs have specific standards and guidelines that need to be met by State agencies. The Forest Stewardship Program has basic guidelines that must be followed to qualify landowners for cost-share assistance. State stewardship committees made up of stakeholders in the program help set priorities for the State program. Periodic program reviews are conducted.

State Laws

Most State forestry agencies are primarily technical service agencies, but some have enforcement responsibility. States may have regulatory responsibilities regarding tax incentive programs or enforcing environmental laws and regulations affecting forest management and harvest activities. For example, the New Jersey Forest Service must inspect or review forest management activities associated with the State farmland tax incentive program and freshwater wetlands laws. Massachusetts can fine landowners who do not follow prescribed forest management practices on harvests above 25 cords.

Nongovernment Requirements

Certification and labeling of forest products is an attempt to balance economic and environmental values of the forest by clearly tracing the source of forest products to a sustainable source. Wood products manufacturers may be certified and their products labeled to indicate that they use technologies that minimally impact the environment. Green certification provides for a voluntary method of enforcement. Voluntary certification can be carried out on a first-, second-, or third-party basis. First-party certification is an internal assessment by an organization of its systems and practices. Second-party certification is

an assessment by a customer or outside trade organization, and third-party certification involves an on-site assessment by a neutral organization based on a set of accepted standards (Hansen 1997).

Members of the AF&PA are required to document their conformance with SFI bylaws to maintain their membership. First-party verification is required to be in compliance with their bylaws, although members may choose to undergo second- or third-party verification and have procedures for such. The overall program is now reviewed annually by an independent expert review panel with its own charter.

The Society of American Foresters code of ethics has an enforcement clause. It relies on its membership to raise issues of ethics violations to the organization.

Indicators 58 and 59 refer to the extent to which the economic framework (economic policies and measures) supports the conservation and sustainable management of forests through the following indicators.

The economic framework is built on allocating scarce resources among competing uses to satisfy human wants and needs. It is chiefly the economic framework that determines whether a society will invest time, money, and labor to use a given product or resource. It is a willingness-to-pay that guides the degree to which people exploit resources or seek balance between their use and availability. The main objective is to maximize benefits and minimize costs. This basic framework is applied to the provision of all goods and services. It is guided by resource supply and product demand. The outcomes or market decisions are based on a series of tradeoffs among production and distribution costs, and profit potential. These principles are the same whether they are applied to the manufacturing of automobiles, soft drinks, breakfast cereal, or forest recreation, water, forage, or timber. The goal, in a free market system, is an optimum or efficient allocation of resources to meet society's needs.

With forests and forestry, however, the dynamics are complex. There are distinct aspects of forestry that are unlike the production of other goods and services. Forests produce varied products on one site, timeframes are confounding, demand is both direct and indirect, and production results in unintended consequences or costs and benefits that are difficult to handle in the typical economic framework.

A forest is the factory for many products simultaneously. There is a dual nature in forest production management. The standing tree is a final product and part of the factory that produces many products. If a management decision for one product is favored, other outputs may be diminished.

Time is an important aspect. Timber production requires longer timeframes than do most other production processes. For example, 25 years between planting and pulpwood harvesting is about average; periods for saw log and veneer log production are longer. Economic analysis methods and decisionmaking processes do not account for long timeframes well and suffer from uncertainty.

Demand is sometimes not direct, but derived. Like many natural resources, forests produce raw materials for industrial use. Factors affecting consumption are sometimes indirect and complicate conservation and management decisions. For example, timber from one part of the country and its price can be influenced by mortgage interest rates in another part of the country and the derived demand for plywood and lumber for homes. Also, derived demand is not handled well for goods and services that do not have organized markets, such as clean water production, aesthetics, or wildlife viewing.

Lastly, externalities of forestry are troublesome. An externality, which can be positive or negative, occurs during the production process and is imposed on another without the permission of or payment to the recipient. Smoke from a factory chimney is an example. Wildlife and watershed protection as a result of timber growing are positive externalities, but when logging and pulp production result in water pollution, this is a negative outcome that imposes social costs. Both types of externalities have unintended effects that confound economic processes.

The economic framework can support the conservation and sustainable management of forests if people value forests for their intrinsic or tangible outputs. Markets determine the flow of goods and services and the best allocation of the varied products from a given forest area. Economic policies influence the retention of forests, the velocity of product flow, and whether products come from public or private forest lands. However, some elements related to forests are not handled well in the economic framework. Traditional economic measures have difficulty capturing the unique diversity of production, its site-specific capacity characteristics, and the value of its nonmarket benefits.

Indicator 58. 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

Investment, taxation, and forest management policies and programs are established or modified to influence people's decisions and behavior with their land. These mechanisms are intended to encourage or discourage actions to meet private or public objectives, and can alter choices and have economic implications for the individual owner and impacts on the public.

Investment Policy

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. Several programs were authorized through the Cooperative Forestry Assistance Act of 1978.

The USDA Forest Service offers the Forest Stewardship Program, designed to encourage forest landowners to manage their forest land under best management practices. It encourages the development of a management plan that raises landowners' awareness about the value of the land they own and the options they have for sustainable management. Forest management

plans such as those produced through the Forest Stewardship Program are required in many States to qualify for additional economic incentives such as preferential tax treatment programs for agricultural and forest uses. The expectation is for an increased private return from the land base and the spillover of benefits to the public.

The Forestry Incentive Program offered by the USDA Natural Resources Conservation Service (NRCS) is a cost-share program for private landowners to encourage reforestation after timber harvests to ensure future timber availability.

Conservation programs focused on agricultural land are public investments to convert marginal land to forests for water quality protection, habitat restoration, and farm income diversification. The Conservation Enhancement Reserve Program administered by NRCS contains practices that create incentives for tree planting and reforestation. Cost sharing is offered to establish and maintain these forests. Compensation for the opportunity cost of foregone crop income is also provided. This incentive operates through a contract that binds the landowner to keep the practice in place for 10 years. This limited period can result in lands reverted to cropping, however, and frequently does if economic conditions signal a greater profit potential from farming the reserved land. Areas that experience significant development pressures are particularly vulnerable to conversion after the contract period. The Federal Agriculture Improvement and Reform Act of 1996 (1996 Farm Bill) expanded this program by way of the Conservation Enhancement Reserve Program, which added increased incentives for selected practices, higher compensation or rental rates for lost income, options for permanent protection compensation, and geographic targeting to address high-priority areas. Favored practices include forest, grassland, and wetland restoration.

The 1996 Farm Bill initiated another NRCS program that focuses on regional needs—the Environmental Quality Incentive Program. It offers additional incentives for practices that protect water quality and soil productivity. Other agriculture programs that offer financial incentives to private landowners to contribute to public good objectives are the Wildlife Habitat Incentive Program, which helps develop and preserve important wildlife habitats for future generations, and the Wetland Reserve Program. Both programs include forest conservation.

Although cost-share incentive programs help landowners meet economic shortfalls, the programs may limit cash flow. Limits to payments keep many landowners off the rolls for these programs and may need to be lifted for the incentives to be effective in some places. The financial reality is that forest returns are typically not collected for long time cycles and can constrain decisions to reforest, invest in forest stand improvement, or retain forest land.

State agencies frequently offer incentives for investments in the State's forest resource. In 1994, northeast and north-central State forestry agencies invested nearly $173 million in a variety of forest resource management and protection programs (NASF 1996). Maryland, for example, has a Woodlands Incentive Program to assist nonindustrial landowners in reforestation, maintenance, and management activities. The State also has a Buffer Incentive Program that offers landowners a one-time payment for planting riparian forests.

The private sector is using an indirect economic incentive approach to promote forest management that takes the long-run view. The AF&PA launched the Sustainable Forestry

Initiative in 1995. The initiative employs five principles and voluntary implementation to reach its objectives. The return to the participating companies is recognition in the industry and promotion to the public. Assuming that the average consumer is motivated to spend their forest products dollars with firms that are conducting "sustainable" forestry, then economic returns can come by way of sales.

Low-interest loans and grants are other investment mechanisms that foster sustainable forest use. The Forest Service Rural Development Program offers financial and technical assistance to help communities and small forest-based businesses develop and succeed. These funds act as catalysts for other private investment and are intended to foster wise and efficient resource use, utilization of locally grown wood, and recycling of products and by-products for profit. These public investments are intended to infuse capital to support start-up business development, and rural economic development and diversification, and to stem the flow out of the forestry sector in rural communities.

Tax Policy

Tax policies may be playing a role in shifting private landownership patterns (Birch 1996a). The number of private landowners is increasing as well as the number of retired owners, and average land tenure and the number of owners tied to the land for income is dropping. Almost half of today's nonindustrial private forest landowners are 55 or older, meaning that many planned and unplanned disposals of property will occur in the near future. Estate taxes will push some of these lands into developed uses and unplanned harvests to pay the tax bill. Owners of smaller tracts may be discouraged from investing in their properties by tax policies that make deducting such expenses difficult (Sampson and DeCoster 1997). These trends may indicate that property tax, capital gains, and estate tax policies are more important than income taxes for future forests.

Property Taxes

When landowners reforest agricultural land it may become subject to higher property tax rates. This can be a deterrent to reforestation or to investment in forestry activities. Some States have adopted use-value and other preferential assessments for forest use as well as agriculture. The real property tax is reduced to reflect the lower costs of community services absorbed by the land use and the benefits it returns to the municipality. Pennsylvania's Farmland and Forest Land Assessment Act of 1974 ("Clean and Green Act") is an example that offers lower taxes for land in productive open space.

Tax Credits

Reforestation tax credits can be applied against Federal income tax liability for expenses incurred for reforestation (Public Law 96–451). The benefit to the landowner depends upon their income level. In general, landowners with substantial income or who have had a significant return from a timber sale will gain the most. Management expenses can also be deducted from pre-tax income.

Capital Gains Taxes

Capital gains taxes can provide an incentive to convert to forests, but can hamper long-term management strategies. A landowner who holds a forest for profit is subject to capital gains taxation at harvest. It is paid on the appreciation in the value of the timber from the time the landowner takes possession until harvest. Whether the landowner is worse off from the income taxed as regular income or as capital gains is dependent on the individual.

Estate Taxes

Estate taxes can have a substantial impact on land tenure and land use. If there is no surviving spouse or estate plan, forest land may change hands or be sold in parcels. Estate taxes can be 37 to 55 percent of the total value of the estate if above the exclusion. The Taxpayer Relief Act of 1997 initiated needed reform. Beginning in 2006, the tax liability will not be initiated until the estate exceeds a value of $1 million ($1.3 million for family-owned businesses). However, the law allows deduction from income taxes, and an exclusion of up to 40 percent of the value of such land (up to $500,000) when placed in a qualified conservation easement (under the provisions of the American Farm and Ranch Protection Act [1997]).

Regulation

More than 80 percent of the Northeastern forest is privately owned. When private management activities are regulated, the pubic bears the costs of education, enforcement, and administration. The private sector also spends money on compliance and legal challenges to regulation. Many regulatory laws that involve forests and forestry are related to habitat preservation and water quality protection from nonpoint sources of pollution. Federal regulations such as the Clean Water Act (1972); the Coastal Zone Management Act of 1972; the Clean Air Act (1990); the Comprehensive Environmental Response, Compensations, and Liability Act (1980); the Federal Insecticide, Fungicide, and Rodenticide Act; and the Endangered Species Act of 1973 all have ramifications on forests and forest practices.

State programs and laws affect forest practices and reforestation efforts. Many States have seed-tree laws that dictate reforestation composition. Twelve States have regulatory water quality laws and eight regulate forest harvest methods (Ellefson and others 1995).

Municipalities and townships are the most common implementers of ordinances and regulations to restrict forestry. These laws are enacted under the intent of protecting aesthetics, reducing erosion, improving water and air quality, and preserving habitat. Laws that limit management and economic gain from forests can unintentionally lead to forest fragmentation and loss to development. One of 3 counties in Delaware, 20 of 23 counties in Maryland, 10 to 15 of 1,200 townships in Michigan, and 300 of 567 municipalities in New Jersey restrict forestry.

Public Land Policy

Public policy decisions can have broad and sweeping effects on the use and availability of forests. Calls for increased acquisition of public land are matched with concerns about reductions in the local tax base, loss of working forests, inadequate funding for maintenance, and an inability of the public sector to effectively manage increased quantities of land with

decreasing staffs and management resources. The Forest Service is not required to pay property taxes on national forests lands; however, most towns do receive compensation to offset the foregone tax revenues. A "25-percent fund" distributes 25 percent of revenues from a national forest to local communities on a per acre basis. If towns dedicate this share to schools, they are eligible to receive additional payments. In 1996, the Forest Service Eastern Region paid almost $20 million to States and communities in lieu of taxes and $17.3 million from the 25-percent fund. There is some controversy regarding this compensation because Congress has not appropriated adequate funding to cover the costs, and reduced timber harvesting lowers payments to communities.

Some State and local laws and programs acquire and conserve forests in perpetuity. Many States have programs to protect riparian areas. For example, Maryland has the Chesapeake Bay Critical Area Act (1984) that controls land use within 1,000 feet of tidal waters and requires a 100-foot naturally vegetated buffer. Exemptions and challenges do result in continued forest loss, and forest management is restricted. Maryland also has a Forest Conservation Act (1991) to protect forest cover during development. Forest stand delineation is required, and areas are designated for forest retention and reforestation. Land trusts and conservancies are producing a significant force across many areas and are buying important forest tracts to ensure that they are available for future generations. Most conservation easements allow timber harvesting, but may restrict the timing and management approach.

Indicator 59. Nondiscriminatory trade policies for forest products

The assumption underlying this indicator is that free trade promotes the efficient use of resources by stimulating competition among producer nations, thereby conserving resources, spurring investment, creating jobs, and reducing prices for consumers. Trade barriers include tariffs on imports but also barriers such as complex regulatory procedures, regulations related to investments and business travel, physical infrastructure, inadequate monitoring, poor information management, and government corruption. Negotiations of free trade agreements among nations generally involve issues of social equity, environmental sustainability, and political diversity, as well as economic opportunity. For example, adoption of environmental standards across international borders could both promote environmental protection and reduce the overall costs of compliance passed on to consumers.

International Agreements and 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 Trade Policy Review Body of the World Trade Organization (2001, p. 1). The United States is signatory to a variety of free trade agreements and generally supports nondiscriminatory free trade policies related to forest products, although there are some restrictions in place, and some segments of the population support protectionist actions (table 7.8). The U.S. tariffs on imports of logs, lumber, plywood, pulp, and paper products are zero or near zero. Many forest products companies in the Northern United States are multinational, and U.S. timber-processing industries support open trade in manufactured products.

A number of countries in the western hemisphere have significant forest products industries that are competitive in regional and world markets. These include Brazil, whose pulp and

Table 7.8. **Free trade agreements and restrictions**. The United States generally supports free trade policies related to forest products, although 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.

paper industry is among the world's lowest-cost producers, and Chile, which has low-cost fiber sources and growing exports. United States exports of pulp, 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). However, tariffs on paper products are high: 5 to 20 percent in Brazil, 11 percent in Chile, 0 to 20 percent in Colombia, and 5 to 20 percent in Venezuela. In addition, a number of countries impose extra fees such as port, handling, and warehouse charges that add to the final cost of importing a product (Smith 1999).

Wood Product Flow

Overall production and consumption of forest products has increased in the United States since 1965, and demand for wood products exceeds domestic production (figure 7.9). Forest product imports increased from 1,604 million to 4,029 million cubic feet (roundwood equivalent) between 1965 and 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.

United States exports have also increased, growing 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) in that order. Most of the trade with Japan probably comes from Western U.S. forests.

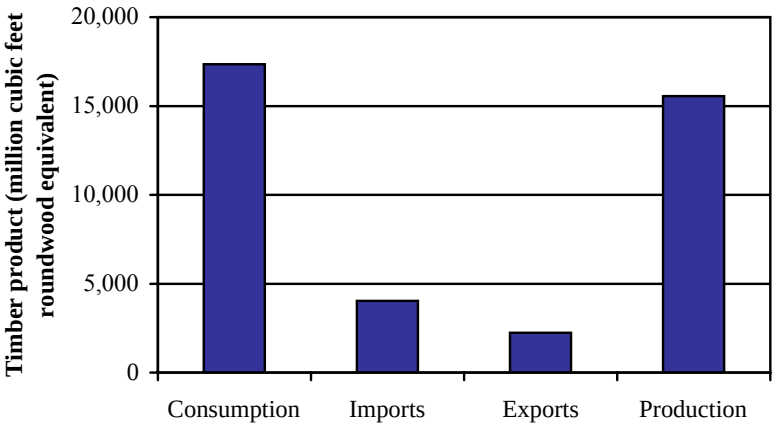

Figure 7.9. **Timber product consumption, import, export, and production in the United States, 1997**. The United States produces the majority of timber products it consumes. Imports supply roughly 23 percent of U.S. consumption of timber products; roughly 14 percent of U.S. production is exported (Howard 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). Roughly 14 percent of the wood harvested was shipped out of the region, mostly to Canada (90 percent). The remainder was shipped to Pennsylvania, southern New England, or exported (35,000 board feet). The region received $250 million from net exports (exports minus imports) of the primary products covered in the study (veneer, sawlogs, pulp, fuelwood, and industrial fuel biomass). The majority of products exported from the region were of high value (e.g., softwood logs), whereas imports were low-value products (e.g., pulpwood and biomass fuel).

Indicators 60 through 62 refer to the capacity to measure and monitor changes in the conservation and sustainable management of forests.

The purpose of inventory, monitoring, and assessment is to provide information that allows citizens and resource managers to accurately evaluate the status of forest health and the effects of forest management, and to debate policy options by using common data. An overall strategy of monitoring and evaluation should address issues and concerns at multiple scales and timeframes. Public and private organizations across the United States conduct inventory and monitoring activities. Public agencies are responsible for ensuring that appropriate information is collected; that the information is complete, accurate, and unbiased; and that it is analyzed by using the best available science. Private corporations and environmental groups may collect information for conservation purposes but do not have to share that information with the general public.

The potential to develop capacity to measure sustainability within the Northern United States is high. The USDA Forest Service Northeastern Area and the Northeastern Area Association of State Foresters have endorsed the use of the Montreal Process criteria as a measurement and reporting framework and are engaged in national efforts to implement the Santiago Declaration. A survey of significant sustainability projects, including national efforts as well as regional, State, county, and city efforts within the Northern United States, yielded 54 projects, 9 of which draw directly from the Montreal Process criteria (Wormstead 2000). The development of this report was considered in the survey.

This report uses the seven Montreal Process criteria as a framework for reporting on the conservation and sustainable management of forests in the Northern United States. It is based on information available mainly from Forest Service programs, but also through information readily available to the Forest Service through existing institutional partnerships, published research, and other published information readily available to the general public. A primary emphasis was placed on conveying the importance of each criterion to sustainability and the relationship of each indicator to the broader criterion. The report is a collaborative effort with the primary contributors drawn from staff of the Forest Service's Northeastern Area, Northeastern Research Station, North Central Research Station, and Eastern Region National Forests, and the Northeastern Area Association of State Foresters (NAASF). The burgeoning of information available on the Internet has also been a key factor in the development of the report.

The process of developing this report is, in a sense, a test of the existing capacity to compile information and report on the Montreal Process indicators at the regional scale. This report will be evaluated for the degree to which it helped to identify emerging issues and to make program and policy decisions at regional and State levels. And it provides a basis for discussion of the linkages between State-, regional-, and national-level reporting. The evaluation of potential data sources for regional reporting and appropriate measurement methodologies has been left for a later date.

Indicator 60. Availability and extent of up-to-date data, statistics, and other information important to measuring or describing indicators associated with criteria 1–7

These indicators deal only with data availability and extent of coverage in the Northern United States. Both quantitative and qualitative information have been used throughout this report. An abbreviated list of primary data sources used and comments regarding measurement of the indicators can be found in table 7.9. The extent of coverage of information for the Northern United States differs by indicator. Case studies were used to identify trends or potential for change in resource conditions for a variety of indicators for which it was not possible to do a regional evaluation with existing information, for example, the measure of fragmentation.

Not all indicators could be addressed with the data as specified in the indicator, so other measures were substituted. For example, watershed-based assessments were used in lieu of forest- or stream-specific measures for many indicators under criterion 4. There are also a variety of ways to interpret the indicators and variety among the specifications used to define terms in different monitoring programs. As an example, multiple definitions of forest land

Table 7.9. **An abbreviated list of data sources used in preparation of the *Forest Sustainability Assessment for the Northern United States*.**

Criterion and indicator	Primary data sources and comments[1]
Criterion 1	**Conservation of biological diversity**
1	USFS FIA eastwide database: includes forest land area estimates by SAF cover type group and USFS province TNC and ABI conservation database: presence of associations includes presence by USFS province USFS urban forest RPA report for area of urban forest
2	USFS FIA eastwide database: age class for timberland only, mixed aged stands identified by Northeast but not North Central inventory unit TNC and ABI conservation database: numbers of globally rare forest and woodland associations by USFS province. Other: USFS urban forest RPA, various old-growth sources
3	IUCN Web site database: inventory of land in IUCN categories USFS FIA eastwide database: reserved forest land Public lands: USFS land areas reports, wilderness and RNA records Land Trust Alliance: not specifically forest land
4	USFS FIA eastwide database: reserved forest land by SAF cover type group USFS: R9 designated old-growth acreage
5	Various subregional fragmentation studies: most used remote sensing USFS: Private landowner survey identifies parcelization as contributing factor
6	Subregional studies: incomplete list of forest-dependent species
7	TNC and ABI: globally ranked species, forest-dependent not broken out USFWS: federally listed threatened and endangered species
8	Wildlife literature and state biodiversity reports: incomplete coverage
9	Wildlife literature and state biodiversity reports: incomplete coverage
Criterion 2	**Maintenance of productive capacity of forest ecosystems**
10	USFS FIA eastwide database: timberland, reserved land, other land USFS landowner survey: owner objectives for timberland
11	USFS FIA eastwide database: timberland by region and species group
12	USFS FIA eastwide database
13	USFS FIA eastwide database: growth to removals on timberland
14	USFS R9 newsletter: synthesis of information on special forest products
Criterion 3	**Maintenance of forest ecosystem health and vitality**
15	USFS FIA (FHM Program): plot data on tree conditions USFS and NAASF Cooperative FHM Program: insects and disease trends North American Maple Project: sugar maple tree conditions Literature: effects of deer browsing
16	USFS FIA (FHM Program): ozone indicator
17	EPA: no area or percentage data
Criterion 4	**Conservation and maintenance of soil and water resources**
18	Discussion: no area or percentage data, erosion potential data not used
19	EPA: number of surface water systems USFWS: wetland loss 1780s–1980s EPA and others: forested stream miles Federal Wild and Scenic Rivers: miles American Heritage River: miles
20	EPA: watershed imperviousness
21	Discussion: no area or percentage data
22	Discussion: no area or percentage data
23	TNC and ABI: aquatic species at risk

[1]See footnote on page 279.

Table 7.9. **An abbreviated list of data sources used in preparation of the *Forest Sustainability Assessment for the Northern United States* (cont.)**.

Criterion and indicator	Primary data sources and comments[1]
Criterion 4	**Conservation and maintenance of soil and water resources (cont.)**
24	EPA: National Watershed Characterization data; Unified Watershed Assessment Ratings Council on Environmental Quality: forest land contribution to nonpoint source pollution, dated figures
25	Discussion: no area or percentage data
Criterion 5	**Maintenance of forest contribution to global carbon cycles**
26	USFS FIA: total carbon calculation uses forest type, extent and age class data
27	USFS FIA: calculation of flux based on successive inventory data.
28	USFS Global Change Program directed to North Atlantic Treaty Organization (NATO) Advanced Studies Institute Report
Criterion 6	**Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies**
29	USFS FIA: forest inventory growth, and removals USDC: Census of Manufacturers
30	Agricultural Statistics Board USFS North American Maple Project USFS National Forest permit records Miscellaneous studies
31	USFS: RPA assessment documents
32	USDC Bureau of Economic Analysis; Northeastern Forest Alliance
33	AF&PA: statistics of paper, paperboard, and wood pulp
34	No quantitative sources
35	USFS: general technical reports
36	USFS: general technical reports
37	USFS: general technical reports
38	USFS: PMAS system AF&PA: statistics of paper, paperboard, and wood pulp
39	Miscellaneous reports
40	USFS Forest Products Laboratory
41	USFS: first approximation report
42	AF&PA Federal land report; USFS Forest Legacy Program
43	Recreation research symposium proceeding; USFS first approximation report
44	USDC: Census of Manufacturers
45	USFS: first approximation report
46	Regional case studies
47	None known
Criterion 7	**Legal, institutional, and economic framework for forest conservation and sustainable management**
48–52	Discussion of Federal laws and mandates and some State laws and mandates USFS: first approximation report Sampson and DeCoster (1997): report on public programs for private forestry American Forest and Paper Association Forest Stewardship Council

[1]See footnote on page 279.

Table 7.9. **An abbreviated list of data sources used in preparation of the *Forest Sustainability Assessment for the Northern United States* (cont.)**.

Criterion and indicator	Primary data sources and comments[1]
Criterion 7	**Legal, institutional, and economic framework for forest conservation and sustainable management (cont.)**
53–59	Discussion of institutional capacities USFS, NRCS, and Cooperative Extension program information Institutional capacities, FSC green certification figures AF&PA: Sustainable Forestry Initiative annual reports Land Trust Alliance USFS: private landowner survey National Research Council report on non-Federal forests Committee of Scientists report: Sustaining the People's Land National Academy of Public Administration: workforce analysis for USFS National Association of Conservation Districts: forestry activity survey AASCU and NASULGC: college graduate employment SAF: accreditation and licensing
60–62	USFS Federal and State cooperative programs information, including FIA Program, FHM Program Detection Surveys, North American Maple Project, National Forest Monitoring
63–67	National Research Council report: Mandate for Change National Research Council report: Prospects and Opportunities for Sustainable Management of America's Non-Federal Forests USFS Research program information McIntyre-Stennis Cooperative Forestry Research Program information

[1]**Acronyms used in this table:**

AASCU	American Association of State Colleges and Universities
ABI	Association of Biological Inventories
AF&PA	American Forest and Paper Association
EPA	U.S. Environmental Protection Agency
FHM	Forest Health Monitoring Program
FIA	Forest Inventory and Analysis Program
FSC	Forest Stewardship Council
IUCN	International Union for the Conservation of Nature
NAASF	Northeastern Area Association of State Foresters
NASULGC	National Association of State Universities and Land-Grant Colleges
NRCS	U.S. Department of Agriculture, Natural Resources Conservation Service
PMAS	Performance Measurement Accountability System
R9	Forest Service Eastern Region
RNA	Research Natural Area
RPA	Forest and Rangeland Renewable Resources Planning Act of 1974 ("Resources Planning Act")
SAF	Society of American Foresters
TNC	The Nature Conservancy
USDC	U.S. Department of Commerce
USFS	U.S. Department of Agriculture, Forest Service
USFWS	U.S. Fish and Wildlife Service

and reserved land exist. The large amount of private landownership and mixed land cover patterns add an element of complexity to the use of the Montreal Process indicators in the Northern United States.

A good deal of information to address the Montreal Processes indicators is available from public institutions, but not all is well summarized, such as information on private conservation, and research and education efforts. Information from Federal agencies and national organizations is quickly making its way onto the Internet, which is helpful.

Information may not always be current. For example, the regional wetland loss data available for this report is from the 1980s, and trends in the last 20 years are not well documented. The Forest Service Forest Inventory and Analysis Program, whose information was heavily relied upon for indicators of criteria 1, 2, 3 and 5, is converting to an annualized inventory to deal with issues of currentness.

To address the Montreal Process indicators in the Northern United States there is a need for the following:

- Better information on historical baseline conditions related to forested area, representativeness of protected lands, populations of forest-dependent species, and cumulative effects from natural and human agents of disturbance, especially for criteria 1, 3, and 4.
- Information specific to forested areas, particularly for criteria 1 and 4.
- Information on private forest land conditions, resource demands on private forest land, and forest land management activities, particularly for criteria 1, 4, and 6.
- Region- and ecosystem-wide information on growth, harvest, and demand for nontimber products.
- Baseline data for forest ecological processes.
- Regional information on State forest land conditions, management practices, policies, and set-asides for criteria 1, 4, 6, and 7.
- Some framework to document systems-based research and research efforts from private, State, Federal, and university sources for criterion 7.
- Information on nonprofit organization conservation efforts and outcomes for criteria 6 and 7.

Indicator 61. Scope, frequency, and statistical reliability of forest inventories, assessments, monitoring, and other relevant information

National, regional, and statewide inventories, monitoring, and assessments can be conducted for strategic planning purposes, for tactical planning of projects, and to prioritize investments. Detailed inventory and monitoring is used in project planning and to monitor the effectiveness of projects once they are implemented. The scope, frequency, and statistical reliability of forest inventory and monitoring information are tied to design scale. Broad-scale forest inventories are often based on statistically designed plot networks that allow extrapolation of data for mapping purposes. Remote sensing provides complete spatial coverage at a given resolution, but it must be combined with data from ground-truth fieldwork. Field-scale inventories use classifications to identify features of interest and map them.

Inventories are increasingly being provided in databases that can be queried and in digital formats that can be mapped by using geographic information systems. Computer-based information systems allow for the analysis of more information and more complex information with higher reliability, consistency, and accuracy than in the past. However,

changing technologies and inventory methodologies affect the accuracy of trend analyses as differences in data definitions and methods can affect inventory figures.

Public and private entities throughout the Northern United States conduct forest inventory and monitoring at a variety of scales depending upon their purposes. Private organizations are under no obligation to share inventory information. This discussion focuses on forest inventory, monitoring, and assessments useful for assessing sustainability within the Northern United States. Forest inventories ultimately need to be integrated with social, cultural, and economic information to achieve sustainability.

Forest Inventory and Analysis Program

The USDA Forest Service Forest Inventory and Analysis (FIA) Program is national in scope, covering both public and private lands by using a statistically based sampling scheme. A reorganization recommended by the 1998 Farm Bill required integration of the Forest Health Monitoring (FHM) Program plot network with the FIA Program plot network. The program strategy is to use a three-phased annualized survey on a statewide basis. In phase 1, the survey identifies forested and nonforested land and provides for spatial measurements such as fragmentation, urbanization, and distance variables—in the past by using aerial photos, now by using satellite data.

Phase 2 involves measurements on field sample plots. All plots include information on species, size of trees, tree growth, mortality, etc. In the past, phase 2 plots were inventoried one State at a time within the two sampling regions of the Northern United States, until all the States had been surveyed, and then the cycle would begin again. Thus, each State would have a periodic sample, in theory, every decade, although, in fact, the cycle was usually longer. Under a revised methodology, the FIA Program measures one-fifth of all field plots in every State every year.

Phase 3 measurement involves a systematic grid of plots (figure 7.10) that exist as a subset of phase 2 plots. At these plots, also known as FHM plots, data include a full vegetation inventory, tree and crown condition, soil characteristics, lichen diversity, coarse woody debris, and ozone damage. As a subset of phase 2 plots, one-fifth of these plots will be measured every year. The FHM Program began in the Northeastern States in 1990 and in the North Central States in 1994. By 2000, all 20 of the Northern States had established their FHM plot networks. In 1998, the health of 266 forested plots, including 6,209 trees, 1,539 saplings, 8,342 seedlings, and 797 standing dead trees, was monitored in the Northern United States. The FIA surveys can be enhanced at the regional, State, and local levels to address special interests.

The plot network for phase 2 FIA plots is established with approximately one plot per 6,000 acres; the phase 3 FHM plots are established approximately one plot per 158,000 acres. If desired, surveys can be intensified by increasing the number of plots by a factor that would increase the statistical reliability at a more local scale and still retain statistical links to the broader scale monitoring network. For example, the State of Minnesota has intensified its forest health monitoring grid by a factor of three.

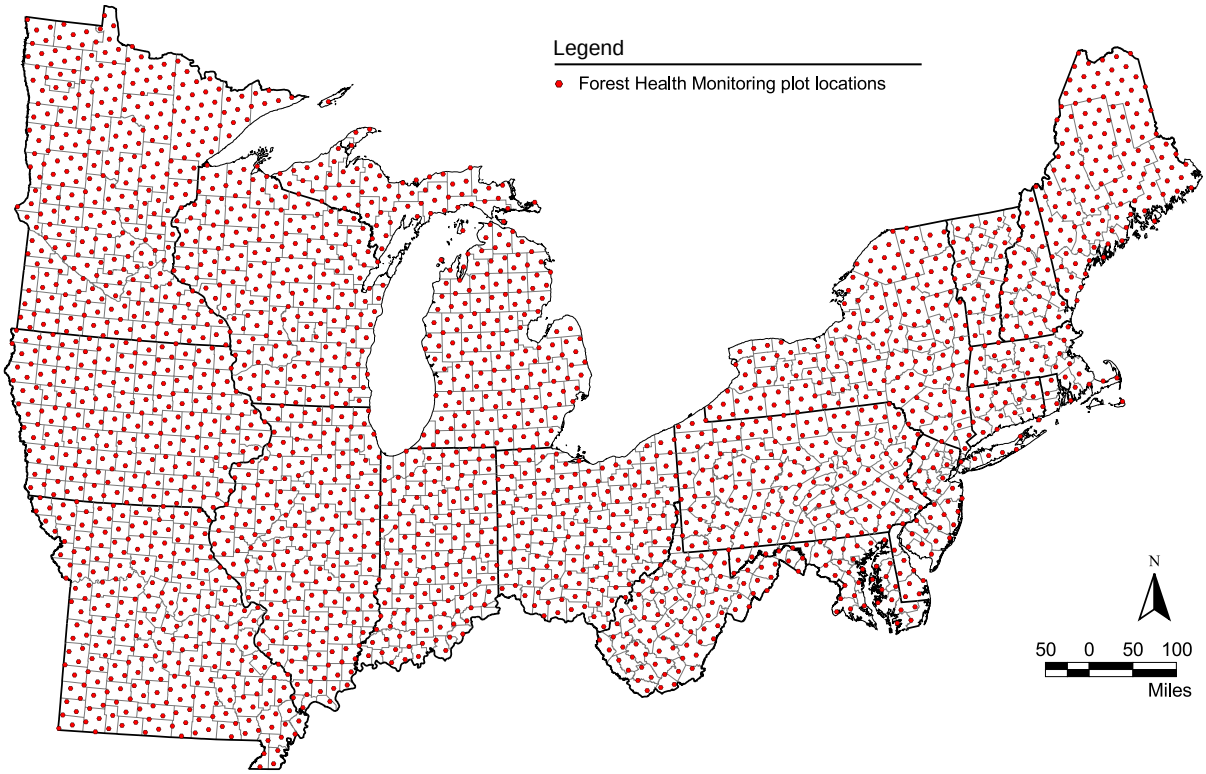

Figure 7.10. **Distribution of Forest Health Monitoring plots in the Northern United States**.

Forest Health Monitoring Program Detection Surveys

The FHM Program also surveys effects of insects, disease, and other stressors. These surveys use techniques such as aerial photography and remote sensing to detect defoliation, discoloration, dieback, branch breakage, and tree mortality. Insect populations are also monitored by the program. The goal for adequate detection is that more than 90 percent of the time the surveys will be able to detect tree damage or other problems by the time they affect an area of 5,000 acres.

North American Maple Project

In response to concerns about the status of the maple resource and possible effects from acid deposition, the North American Maple Project was begun in 1987 to annually visit selected sugarbush (*Acer saccharum*) stands (stands dedicated to production of maple syrup) and other maple (*Acer* spp.) stands (figure 7.11). The project is administered jointly by the Canadian Forest Service and the USDA Forest Service, and involves 10 Northern States and 4 provinces. The objectives are to look at the rate of change in maple condition, to determine if change is related to various levels of acid deposition, and to ascertain possible causes of any tree decline. The long-term data set provides information on tree condition and mortality.

Monitoring on National Forests

National forests participate in the FIA and FHM Programs. In addition, they conduct inventory, monitoring, and assessments as the basis for changes in standards and guidelines,

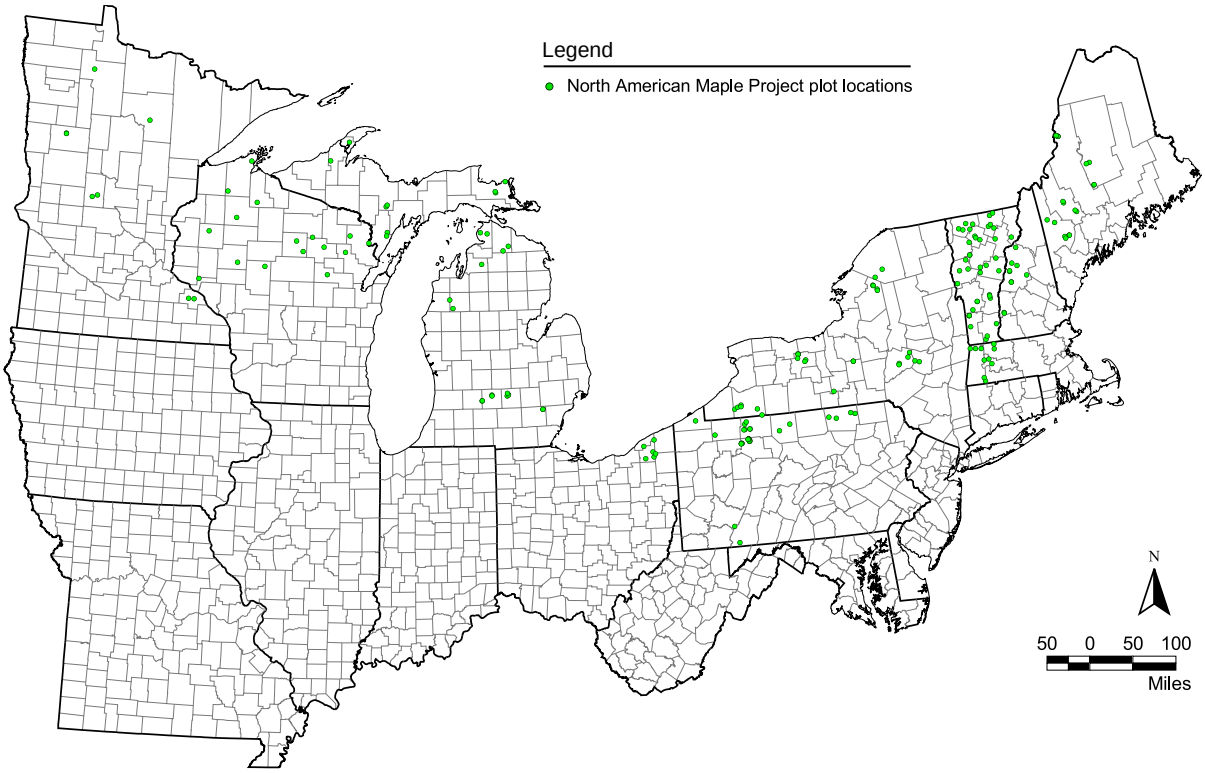

Figure 7.11. **Distribution of North American Maple Project plots in the Northern United States**.

goals, objectives, and other plan direction to meet requirements of Federal laws such as the Endangered Species Act, and to plan and implement projects. The Forest Service Eastern Regional Office in Milwaukee provides regional direction on many but not all inventory and monitoring activities. Staff specialists may design monitoring projects, cooperate on, or contract out monitoring projects.

Remote Sensing of Forest Resources

Remote sensing products such as advanced very high resolution radiometry (AVHRR), Landsat thematic mapper-multispectral scanner imagery (TM-MSS), and Satellite Probatoire d'Observation de la Terra (SPOT) imagery are increasingly used to inventory conditions and trends important to forest sustainability, such as the extent, type, age, and health of forests. Key factors in the proper use of this technology are matching the remote sensing product to the proper scale for analysis and understanding the limitations of the remote sensing instruments and classifications.

For example, Host and Polzer (1997) compared AVHRR and Landsat TM-MSS data and demonstrated differences in estimates of forest acreage by type owing to these two key factors (figure 7.12). The AVHRR imagery provides a coarse-resolution classification (1 square kilometer) suitable for broad-scale trend analysis and covers more area per scene than maps from TM-MSS with finer resolution (30-square-meter pixels). The SPOT imagery is useful in separating wetlands from nonwetlands and urban from nonurban areas at a broad scale but is not a preferred tool for differentiating among forest cover types.

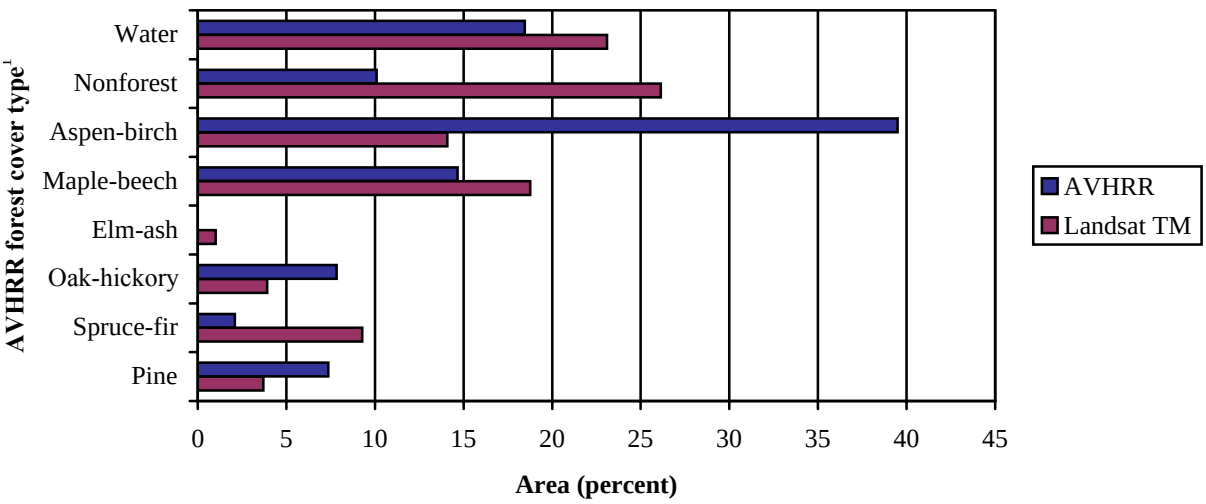

Figure 7.12. **Imagery can affect forest inventory results**. Forest cover type classification and inventory results for advanced very-high-resolution radiometery (AVHRR) differ from those developed by using Landsat thematic mapper (TM) imagery for an area of northern Wisconsin (25-meter resolution). The AVHRR exaggerated the amounts of certain cover types such as aspen-birch and underestimated the amount of nonforested land (Host and Polzer 1997).

[1]Forest cover types are different from those obtained from the Forest Inventory and Analysis Eastwide Database (USDA Forest Service 1999b).

Indicator 62. Compatibility with other countries in measuring, monitoring, and reporting on indicators

Data compatibility issues result from differences in definitions used in inventories and differences in methods used over an assessment area and over time. For example, the definition of "forest land" affects acreage figures. Each remote sensing tool will give a result with its own degree of precision and accuracy. In using GIS to integrate different types of information (i.e., environmental, social, economic), the scale and resolution of data are important. Regional differences in landscapes, populations, or local economies can radically alter the cost-effectiveness of various monitoring methods so that absolute data compatibility is not pragmatic. Some problems can be overcome by bounding environmental, social, or economic or systems at the scale of interest and then using compatible inventory, monitoring, and analysis methods within those units. This is the purpose of ecoregional and watershed analysis units.

National and International

In response to the Santiago Declaration, the United States developed a First Approximation Report (USDA Forest Service 1997a), which reported on the status of the Nation's forests. The publication identified the need for current public forest inventory and monitoring systems to coordinate the definitions, methodology, and protocols used in inventory and monitoring, in order to capture the picture of forestry as it is practiced around the world. It also identified data gaps and data coordination needs in the United States.

The National Roundtable on Sustainable Forests is a multistakeholder forum dedicated to sharing information and perspectives that will enable better decisionmaking in the United States regarding sustainable forests. It established a technical working group to develop a national set of protocols to implement criteria and indicators, to establish a collaborative national arrangement for data collection and reporting of criteria and indicators, and to help develop the *National Report on Sustainable Forests 2003*. The roundtable also is helping support United States participation in the forum provided by the Santiago Declaration.

Federal inventory and monitoring programs continually work to provide consistency and comparability to data inventory within and across agencies of the Federal government. For example, work is underway to implement more uniform design and data collection standards and to examine opportunities to better integrate FHM, FIA, and National Forest System inventories. The FHM protocol is nationally and internationally consistent. State forestry agencies are part of the FIA and FHM Programs and work cooperatively to implement them, lending consistency to data collection. The Forest Service FIA phase 1 and 2 plots use the U.S. Environmental Protection Agency (EPA) national hexagonal base grid that is also used by the EPA Environmental Monitoring and Assessment Program.

Northern United States

Data compatibility is an important issue for management units that share ecosystems, watersheds, or program implementation responsibilities. The USDA Forest Service (Northeastern Area, Eastern Region, North Central Research Station, and Northeastern Research Station) and NAASF are cooperating with national efforts described above to identify common measurement and reporting protocols, many of which will also provide for data compatibility at the regional and State levels within the Northern United States. In addition, the Northeastern Area and NAASF will evaluate a limited set of indicators to meet regional and State needs to measure progress in sustainability.

Indicators 63 through 67 refer to the capacity to conduct and apply research and development aimed at improving forest management and delivery of forest goods and services.

Ten years ago, the National Research Council (1990, p. 3) declared that forestry research nationally was “inadequate to meet society’s needs.” The council identified major forestry research needs similar to those identified in indicators 63 through 67. It identified shortfalls in the scope of research conducted at that time and the number of scientists participating in basic forestry research, and it cited fragmentation of leadership among existing institutions as a factor limiting progress in addressing these shortfalls.

Similar overarching issues dealing with research activities and the organization and management of research were raised following an evaluation of research pertaining to non-Federal forests (National Research Council 1998). In addition, they cited the need to increase the number and funding of research projects dealing with private forest land management issues. Although acknowledging that the need for basic research is similar and applicable

across ownership boundaries, the council pointed out that the variety of objectives associated with management of private, industrial, and State forests argues for a research agenda that accommodates the information needs of non-Federal sectors. Forest products industry research and development activities also appear to fall short of those needed to ensure that the U.S. forest products industry can remain competitive in the global marketplace while still conserving and protecting forest resources and values (Ellefson and Ek 1996).

The National Research Council report *Forestry Research: A Mandate For Change* called for research to address the biology of forest organisms, ecosystem function and management, human-forest interactions, wood as a raw material, and international trade, competition, and cooperation (National Research Council 1990). Major research topics are listed in the box below.

Recommended Topics of Forestry Research (National Research Council 1990)

- Understand basic biology and ecology of forests.
- Develop information to sustain productivity of forests as well as protect their inherent biological diversity.
- Design and implement landscape-level and other large-scale, long-term experiments.
- Understand the economic and policymaking processes that affect the fates of forests.
- Develop systems of forest management that simultaneously produce commodities and maintain and improve environmental values.
- Integrate the social component into research on forest ecosystems, which can then be applied to management practices.
- Develop harvesting systems that recover timber values without degrading other values.
- Improve the efficiency of production and utilization of new and traditional wood products.

The institutional infrastructure of Federal, State, and private research and educational facilities is well developed in the Northern United States. A variety of Federal, State, and private 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.

USDA Forest Service Research

The USDA Forest Service has had a research branch since the agency was formed in 1905. Experiment stations, research laboratories, experimental areas, and other forest and rangeland research facilities operate under the authority of the Forest and Rangeland Renewable Resources Research Act of 1978. Two of seven Forest Service research stations are located in the Northern United States—the North Central Research Station and the Northeastern Research Station. These stations consist of about 40 project work units among 18 field offices and 22 experimental forests and watersheds. Historical 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. Issues that are more recent include acid deposition, global climate change, and international forestry.

The forest research community is looking for linkages and integrating principles among individual disciplines. Systems-based approaches are seen as a means of bridging disciplines. The North Central Research Station has launched three integrated research programs to focus on critical natural resource concerns in the Midwest: managing riparian landscapes, understanding and managing landscape change, and managing forests more productively (USDA Forest Service 1999a). The Northeastern Research Station has identified nine specific research issues that contribute to four broad research emphasis areas (table 7.10).

Table 7.10. **Research emphasis areas**. The Northeastern Research Station has identified nine specific research issues that contribute to four broad research emphasis areas (USDA Forest Service 1996a).

Research issue	Emphasis area			
	Understanding ecosystems	Managing ecosystems	Protecting ecosystems	Utilizing ecosystems
Basic processes	X			
Disturbance and ecosystems dynamics	X	X	X	
Forest processing, production, and use		X		X
Inventory and monitoring	X	X	X	
Managing forest health	X	X	X	
Silviculture and resource management	X	X		X
Social and economic dimensions	X	X	X	X
System modeling and integration	X	X	X	X
Wildlife	X	X		X

Research agencies in Federal and State government and in private industry have been affected by the widespread downsizing and restructuring common across America in the last decade. In the Federal government, reduced operating budgets and personnel levels have affected the amount and duration of research projects. The need to leverage resources has the positive effect of forcing research organizations to look for opportunities to collaborate on projects and to expand research networks. There is widespread concern that important research needs will be ignored unless comprehensive planning across the research community occurs, or that research will feel it is necessary to sensationalize results in order to garner funding for projects.

Nationally the number of scientists in the Forest Service research and development workforce has decreased by 45 percent between 1985 and 1999, from 978 to 537. There has been a reallocation of staff among disciplines and a change in the suite of skills within disciplines (table 7.11). Within the discipline of biological sciences, there has been an increase in the proportion of personnel working as ecologists, wildlife and fisheries biologists, and plant physiologists and a decrease in research foresters, entomologists, plant pathologists, and range scientists (NAPA Center for Human Resources Management 1999).

Table 7.11. **Comparison of scientific discipline representation in the USDA Forest Service research and development workforce** (NAPA Center for Human Resources Management 1999).

Discipline area	1985 workforce	1990 workforce	1999 workforce
		Percent	
Biological sciences	69.5	75.5	73.9
Physical sciences	15.7	12.5	12.1
Engineering	6.5	6.5	6.1
Social sciences	2.9	2.8	5.0
Math/statistics	3.6	3.5	2.8

Universities and Colleges

In 2000, $76.4 million out of $226.6 million nationally was invested in forestry research at 33 universities in the Northern United States (figure 6.9 on page 193). Fifty-two percent of this funding was provided by State governments and nearly one-third by Federal government sources. Almost half of the Federal support, $10.9 million, was through USDA Cooperative State Research, Extension, and Education Service (CREES) programs, including McIntire-Stennis funds. Based on 1999 and 2000 data, McIntyre-Stennis funds leveraged $9 for every Federal dollar for forestry research and graduate education (USDA CSREES 2003).

Industry

The majority of forest industry research is directed to the development, processing, marketing, and use of forest products rather than basic scientific or management research (Ellefson and Ek 1996).

Other

The USDA Agricultural Research Service supports research beneficial to forestry. Other USDA agencies, such as NRCS and CREES, the Departments of the Interior and Energy, and the Environmental Protection Agency conduct and fund research and extension activities useful for forest management. The National Aeronautics and Space Administration and the National Oceanic and Atmospheric Agency are increasingly important players in forestry research as remote sensing technologies and extensive data sets are becoming important in broad-scale investigations.

Indicator 63. Development of scientific understanding of forest ecosystem characteristics and functions

Development of scientific understanding of forest ecosystems falls within the realm of basic research, one of the areas highlighted as inadequate by the National Research Council (1990, 1998). Ecosystem research involves studying the interactions among ecosystem composition, structure, and function. It involves study of individual species' adaptive traits at multiple spatial and temporal scales. This research involves multidisciplinary studies, a combination of intensive and extensive data-gathering efforts, and the ability to build and verify results of empirical and theoretical system-based models.

Ecosystem studies benefit from being conducted within a stable institutional framework to ensure continuity of research in spite of staff turnover. The research infrastructure seems to be in place in the Northern United States. The Forest Service maintains 22 experimental forests and watersheds for long-term research into forest and watershed management throughout the Northern United States (appendix 7–G). Besides the public colleges, universities, and research institutions cited above, the Northern United States is home to many high-quality private colleges and institutions, biological stations, and independent research organizations.

Progress in forest ecology, landscape ecology, conservation biology, and genetics, which are 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. Out of 21 Long-Term Ecological Research (LTER) Program sites established across the Nation, 7 are located in the Northern United States, and 5 of these deal intensively with forested ecosystems (appendix 7–H). The core research topics of the LTER sites include (1) pattern and control of primary production, (2) spatial and temporal distribution of populations selected to represent trophic structure, (3) pattern and control of organic matter accumulation in surface layers and sediments, (4) patterns of inorganic inputs and movements of nutrients through soil, groundwater, and surface water, and (5) patterns and frequency of site disturbances. The LTER research studies are carried out by a broad range of agencies, companies, and nonprofit organizations and cover urban to rural, marine, aquatic, and terrestrial ecosystems.

Sophisticated, sensitive equipment is often quite expensive, and the ability to obtain state-of-the-art equipment influences an institution's ability to compete for highly qualified personnel and to attract research funding. Similarly, geospatial analysis is a critical component of many basic studies.

Indicator 64. 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

Methods that effectively measure a range of environmental and social values would enable the public to better understand the tradeoffs inherent in environmental, social, and economic policies and to better discuss the equitable distribution of costs and benefits among individual citizens and the general public. An example application would be to evaluate public tax and zoning laws to see what incentives and disincentives private forest landowners have to develop or retain their land, and to balance the private costs and benefits against the conservation or loss of public benefits such as water quality, air quality, biodiversity, and an aesthetic living environment.

Four Forest Service research work units touch upon themes in this indicator (table 7.12). Three of them focus on developing methods to measure and integrate environmental and social costs and benefits into public policies and management decisionmaking. One touches on forest-related resource depletion by integrating supply, demand, and product utilization trends. These units do not fill the need for research on methods to integrate environmental and social costs into markets and regional or national accounting systems. Collaboration among environmental, social, and economic scientists is needed to develop methods to measure and integrate social costs and benefits into markets and public policy if natural and social capital, as well as economic capital, are to be conserved.

Table 7.12. **Social and economic research**. Several USDA Forest Service work units are researching methods to anticipate supply and demand for forest resources and to integrate environmental and social costs and benefits into public policies and landowner decisionmaking.

Work unit	Research activity
North Central Research Station	
Forest Economics	Ways to evaluate the costs and tradeoffs of alternative management strategies to sustain forests, enhance productivity and achieve output goals in the North Central United States. Includes means to assess the economic, demographic, and social factors affecting forests and communities in the region.
Social and Economic Dimensions of Ecosystem Management	Conduct integrated, interdisciplinary research on the linkages and interactions between social systems and ecosystems, particularly as they relate to ecosystem management. This research includes methods to track changes in people's values over time and means to involve people with different values in forest planning and decisionmaking.
Northeastern Research Station	
Integrating Ecological and Social Dimensions of Forest Ecosystem Management	Systematically assess a spectrum of nonmarket values related to forest benefits and to identify indicators of sustainability of ecological and social systems.
Forest Products and Use Economics	Understand patterns of demand, production, and utilization of products from the predominantly hardwood forests of the Northeastern United States.

Interest is increasing, nationally and internationally, in including the environment and social costs in national income accounts. Conventional economic accounting systems recognize limits of financial and technological capital and labor limits but not the biophysical limits of what the environment can produce or absorb by way of disturbance or pollution. Likewise, conventional accounting systems tend to ignore or discount the value of future social benefits and costs. They do not consider the degree to which actions today foreclose choices for future generations or even the uncertainty that one can anticipate future preferences, as indeed, social values reflect moral and cultural factors that differ by individual and community.

The task at the national level would fall to the Bureau of Economic Analysis (BEA) in the U.S. Department of Commerce, Economics and Statistics Administration. The BEA conducted a study of the country's ability to implement the United Nations Environmental and Economic Accounting System and has looked at forests as national income accounts. Apparently, significant work would be needed to establish a system to collect environmental and economic data suitable to implement the United Nations system (USDA Forest Service 1997a). And although it is difficult to develop methods and institutions to measure environmental and social costs and benefits, the potential to reallocate costs and benefits among stakeholders under a changed system has made implementation through markets and public policy a political challenge as well.

There is increasing recognition of the use of indicators as a viable means of measuring and integrating environmental, social, and economic costs and benefits. Indicators such as environment, community, quality of life, and sustainability are being used by more and more organizations to gauge progress in efforts to balance economic well-being, the environment, and social equity. For example, the organization Redefining Progress (http://www.rprogress.org) has proposed a genuine progress indicator as an alternative to the gross domestic product (GDP) that is currently used to measure U.S. economic growth. According to Redefining Progress, not all spending counted as progress under the formula to determine GDP results in real increases in quality of life. The Green Mountain Institute for Environmental Democracy (http://www.gmied.org) helps State agencies, Federal agencies, local communities, and nongovernment organizations develop and use indicators to track progress toward community and agency goals and to assess the condition of valued resources and trends that might influence them.

Indicator 65. New technologies and the capacity to assess the socio-economic consequences associated with the introduction of new technologies

New technology that improves forest management and the delivery of forest goods and services can have positive and negative effects on social and economic systems, in addition to effects on the ecosystem. Traditionally, the research focus in forestry has been on the economic efficiency of adopting innovations in timber harvesting, wood processing, and wood products such as changes in harvesting equipment, logging practices, processing technologies, and products rather than the effects of adopting this technology on social and economic systems. Forest management technologies and nontimber goods and services, such as outdoor recreation, forest health protection, and tourism, deserve more study.

The Forest Service's Forest Products Laboratory, Timber Demand and Technology Assessment Work Unit evaluates the economic impacts of wood products and paper technologies. It also evaluates effects on supply, employment, trade, carbon cycling, and, to some degree, air and water emissions.

Indicator 66. Enhancement of ability to predict impacts of human intervention on forests

The effects of human intervention on forests is an extremely broad area that would include research on global environmental change, loss of biodiversity, acid deposition, loss of wetlands, loss and alteration of wildlife habitat, exotic species introductions, toxic contaminants, pollution, land use practices, management practices, and anthropogenic disturbances.

Technology has increased our ability to measure and model environmental changes. Advances in remote sensing and geospatial modeling techniques have increased predictive capabilities, although a critical limiting factor is often the resources to conduct ground-truth investigations at an appropriate scale. Predictive modeling is also dependent on an increased understanding of the feedback mechanisms among ecological conditions, economic systems, and human behavior.

The Hubbard Brook Experimental Forest in New Hampshire and the Fernow Experimental Forest in West Virginia are two Forest Service research sites dedicated to furthering research on the interactions between forest ecosystems, forest management, and water quality.

Indicator 67. Ability to predict impacts on forests of possible climate change

To reduce the vulnerability of the human population and ecological systems to major environmental changes, it is critical to increase scientific knowledge about the causes and effects. The ability to predict the effects of climate change on forests requires a comprehensive investigation of the Earth's systems and the responses of humans to changing conditions. Understanding these diverse interactions and scales of interaction requires the participation of an extensive community of scientists from a wide range of scientific disciplines and from all regions of the globe.

United States Global Change Research Program

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 by the Global Change Research Act of 1990. The USGCRP draws expertise from 18 departments and agencies of the Federal government. The USGCRP research is organized to observe, document, understand, and predict global change; to assess the consequences of these changes and the vulnerability of human and ecological systems to their potentially adverse impacts; to develop the tools and capabilities to conduct integrated assessments; and to synthesize and communicate this body of knowledge.

Research and program objectives through the year 2010 include the following (USGCRP 2000):

- Determine the origins, rates, and likely future course of natural and anthropogenic changes.
- Increase understanding of the combined effects of multiple stresses on ecosystems.
- Understand and model global environmental change and its processes on finer spatial scales and across a wide range of timescales.
- Address the potential for surprises and abrupt changes in the global environment.
- Understand and assess the effects of global environmental change and their consequences for the United States.

National Assessment

The USGCRP has drafted a national assessment to analyze and evaluate what is known about the potential consequences of climate variability and change for the United States. The assessment includes sectoral and regional analyses, and a national synthesis effort. Sectoral analyses consider the potential consequences on five major economic sectors: health, water, forests, agriculture, and coastal areas. These analyses are quantitative and national in scope. Regional analyses identify and characterize potential consequences on 20 geographic regions throughout the United States. There are six regions in the Northern United States: the Appalachian, Eastern Midwest, Great Lakes, Metro East, Mid-Atlantic, and New England Regions.

The national synthesis draws together the results of the regional and sectoral analyses. Common climate and socioeconomic scenarios are being used to derive information for each of these components, to test sensitivities, and to develop information that can be effectively synthesized. Modeled scenarios emphasize potential consequences over the next 25 to 30 years and also over the next 100 years. Following the issue of this first report, periodic reports with additional sectors and analyses are expected. This national assessment is expected to contribute significant information for a third assessment report of the Intergovernmental Panel on Climate Change that is used in international and national policy formulation.

The forests sectoral assessment for the national report is focused on changes that may occur in forests with climate change: specifically, productivity, species diversity, potential changes in carbon storage, and changes in water availability. The assessment also considers possible alterations in physical and chemical atmospheric properties that may drive changes in the forests, the role of social and economic shifts in changing the character of forests, and the role that changing climate and climate variability may have on disturbance factors such as pests, fires, and disease within forest ecosystems.

Northern Global Change Research Program

The Northern Global Change Research Program, which looks at climate change as it affects forestry in the Northern United States, is part of the Forest Service Global Change Research Program. Questions that guide Northern Global Change Research projects are:

- What processes in forest ecosystems are sensitive to physical and chemical changes in the atmosphere? (Is there a problem?)
- How will future physical and chemical climate changes influence the structure, function, and productivity of forest and related ecosystems, and to what extent will forest ecosystems change in response to atmospheric changes? (What is the problem?)
- What are the implications for forest management and how must forest management activities be altered to sustain forest productivity, health, and diversity? (What can be done about the problem?)

Summary and Conclusions

The legal and institutional framework to support sustainability and achieve a balance between public and private interests is in place in the Northern United States. However, public institutions nationally and in the Northern United States are stressed by the rapid pace of social, demographic, and technological change combined with government budget cutting, restructuring, and personnel reductions. State and Federal forestry agencies have historical plot data on forest types, age, distribution, and health throughout the Northern United States. Human-natural resource interactions are complex, and much work remains to be done, especially in the arena of social and economic indictors. 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, with some exceptions, the latter are more willing to work with public and industrial organizations by using collaborative problem-solving approaches.

The economic framework includes both incentives and disincentives to sustainability. Demand for forest resources continues to increase at a pace even more rapid than population growth. As yet, there is no widely used systematic means of accounting for nonmarket services provided by natural resources; therefore, they continue to be undervalued or excluded from economic forecasts. Generally, analytical techniques and decisionmaking processes do not account well for long timeframes and suffer from problems of uncertainty. The government must focus on sustaining forestry resources for the long term as should research.

Private management decisions are often constrained by short-run considerations and market signals, while investments in forestry are long term. Trees take longer to grow than the production of most products, 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 decisions 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.

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.

Appendix 7–A. National forest land and water areas, 1998

National forest	State	Gross land area[1]	Gross water area[1]	Gross land and water area (total)[1]	Net area[2]	National forest area[3]
		----------Acres----------				Percent
Allegheny	PA	741,562	1,131	742,693	513,118	69
Chequamegon	WI	1,031,299	18,242	1,049,541	860,254	83
Chippewa	MN	1,314,384	285,276	1,599,660	666,269	51
Finger Lakes	NY	16,164	—	16,164	16,164	100
Green Mountain	VT	816,660	—	816,660	367,925	45
Hiawatha	MI	1,273,420	21,225	1,294,645	893,945	70
Hoosier	IN	643,660	469	644,129	195,864	30
Huron	MI	691,404	2,653	694,057	443,912	64
Manistee	MI	1,314,992	16,681	1,331,673	535,892	41
Mark Twain	MO	3,002,967	9,498	3,012,465	1,494,246	50
Monongahela	WV	1,650,951	—	1,650,951	896,872	54
Nicolet	WI	943,147	30,258	973,405	661,879	70
Ottawa	MI	1,522,556	37,352	1,559,908	983,680	65
Shawnee	IL	711,994	2,896	714,890	267,793	38
Superior	MN	2,975,618	285,012	3,260,630	2,092,097	70
Wayne	OH	832,147	—	832,147	227,373	27
White Mountain	ME	53,561	—	53,561	42,363	79
White Mountain	NH	799,816	—	799,816	702,311	88
Total		**20,336,302**	**710,693**	**21,046,995**	**11,861,947**	**58**

[1]Total area within the boundaries of National Forest System unit(s) plus National Forest System acreage outside of the boundaries of National Forest System unit(s). Some private holdings exist within National Forest System unit boundaries.
[2]National Forest System area, administered by the Forest Service. Does not distinguish whether the area is inside or outside of National Forest System unit boundary(s).
[3]Percentage of National Forest System area within the unit boundary.
Source: USDA Forest Service 1997b, 1998b, 2004.

Appendix 7–B. Status of State and national forest resource plans in the Northern United States

State	Status	
	State resource plans	National forest plans
Connecticut	1985[1]	
Delaware	1983,[1] 1990[1] 2000[1] DE statewide forest resource plan	
Illinois	1984, 1999 1990 Long-range plan 1994 IL Dept. of Conservation strategic plan 1999 IL statewide forest resource plan	Shawnee 1986 Significant amendment 1992 Under revision 2000
Indiana	1981[1] 1996 Strategy for State forest land properties	Hoosier 1985 Significant amendment 1991
Iowa	1985,[1] 1990, 1995[1]	
Maine	1985[1] 1999 First mandated state-of-the-forest report plus periodic dept. agency, division, and program strategic plans	
Maryland	1988[1]	
Massachusetts	1985[1]	
Michigan	1983[1] 1990s Several addendums on specific issues and State forests	Ottawa 1986 Hiawatha 1986 Huron-Manistee 1986
Minnesota	1983,[1] 1987, 1991 1994 Generic environmental impact statement 1995 Forest planning assessment 1998 Forest council vision and goals	Superior 1986 Under revision 2000 Chippewa 1986 Under revision 2000
Missouri	1983,[1] 1991	Mark Twain 1986
New Hampshire	1952, 1964, 1982[1] 1996[1] NH statewide forest resource plan	White Mountain 1986 Under revision 2000
New Jersey	1983[1]	
New York	1985[1]	Finger Lakes 1987 Under revision 2000
Ohio	1983[1]	Wayne 1988
Pennsylvania	1985,[1] 1995	Allegheny 1986
Rhode Island	1984[1]	
Vermont	1986,[1] 2000[1]	Green Mountain 1987 Under revision 2000
West Virginia	1984,[1] 2000 State forest land plans	Monongahela 1986
Wisconsin	1983,[1] 1989,[1] 2001[1]	Chequemegon/Nicolet 1986

[1]Developed through the Federal Cooperative Planning Program.
Source: Carpenter 2000, Emmons 2000.

Appendix 7–C. Wilderness areas in the Northern United States

Wilderness	Acres	Administered by[1]
Illinois		
Bald Knob	5,863	Shawnee National Forest
Bay Creek	2,866	Shawnee National Forest
Burden Falls	3,671	Shawnee National Forest
Clear Springs	4,730	Shawnee National Forest
Crab Orchard	4,050	Crab Orchard National Wildlife Refuge
Garden of the Gods	3,268	Shawnee National Forest
Lusk Creek	4,466	Shawnee National Forest
Panther Den	774	Shawnee National Forest
Illinois Total	**29,688**	
Indiana		
Charles C. Deam	12,953	Hoosier National Forest
Indiana Total	**12,945**	
Maine		
Caribou-Speckled Mountain	12,000	White Mountain National Forest
Moosehorn	2,712	Moosehorn National Wildlife Refuge
Moosehorn (Baring Unit)	4,680	Moosehorn National Wildlife Refuge
Maine Total	**19,392**	
Massachusetts		
Monomoy	2,420	Monomoy National Wildlife Refuge
Massachusetts Total	**2,240**	
Michigan		
Big Island Lake	5,856	Hiawatha National Forest
Delirium	11,870	Hiawatha National Forest
Horseshoe Bay	3,790	Hiawatha National Forest
Huron Islands	147	Huron National Wildlife Refuge
Mackinac	12,230	Hiawatha National Forest
McCormick	16,532	Ottawa National Forest
Michigan Islands	12	Shiawassee National Wildlife Refuge
Nordhouse Dunes	3,450	Manistee National Forest
Rock River Canyon	4,640	Hiawatha National Forest
Round Island	378	Hiawatha National Forest
Seney	25,150	Seney National Wildlife Refuge
Sturgeon River Gorge	12,925	Ottawa National Forest
Sylvania	18,327	Ottawa National Forest
Michigan Total	**115,307**	
Minnesota		
Agassiz	4,000	Agassiz National Wildlife Refuge
Boundary Waters Canoe	808,974	Superior National Forest
Tamarac	2,180	Tamarac National Wildlife Refuge
Minnesota Total	**815,154**	

[1]National wildlife refuges are administered by the U.S. Fish and Wildlife Service. National seashores are administered by the National Park Service.
Source: USDA Forest Service 1997b.

Appendix 7–C. Wilderness areas in the Northern United States (cont.)

Wilderness	Acres	Administered by[1]
Missouri		
Bell Mountain	8,977	Mark Twain National Forest
Devils Backbone	6,595	Mark Twain National Forest
Hercules-Glade	12,315	Mark Twain National Forest
Irish	16,277	Mark Twain National Forest
Mingo	7,730	Mingo National Wildlife Refuge
Paddy Creek	7,019	Mark Twain National Forest
Piney Creek	8,087	Mark Twain National Forest
Rockpile Mountain	4,089	Mark Twain National Forest
Missouri Total	**71,089**	
New Hampshire		
Great Gulf	5,552	White Mountain National Forest
Presidential Range –Dry River	27,380	White Mountain National Forest
Pemigewasset	45,000	White Mountain National Forest
Sandwich Range	25,000	White Mountain National Forest
New Hampshire Total	**102,932**	
New Jersey		
Great Swamp	3,660	Great Swamp National Wildlife Refuge
Brigatine	6,681	Edwin B. Forsythe National Wildlife Refuge
New Jersey Total	**10,341**	
New York		
Fire Island	1,363	Fire Island National Seashore
New York Total	**1,363**	
Ohio		
West Sister Island	77	West Sister Island National Wildlife Refuge
Ohio Total	**77**	
Pennsylvania		
Allegheny Islands	368	Allegheny National Forest
Hickory Creek	8,663	Allegheny National Forest
Pennsylvania Total	**9,031**	
Vermont		
Bristol Cliffs	3,738	Green Mountain National Forest
Lye Brook	15,503	Green Mountain National Forest
Breadloaf	21,480	Green Mountain National Forest
Big Branch	6,720	Green Mountain National Forest
Peru Peak	6,920	Green Mountain National Forest
George D. Aiken	5,060	Green Mountain National Forest
Vermont Total	**59,421**	

[1]National wildlife refuges are administered by the U.S. Fish and Wildlife Service. National seashores are administered by the National Park Service.
Source: USDA Forest Service 1997b.

Appendix 7–C. Wilderness areas in the Northern United States (cont.)

Wilderness	Acres	Administered by[1]
Wisconsin		
Blackjack Springs	5,886	Nicolet National Forest
Headwaters	18,188	Nicolet National Forest
Porcupine Lake	4,292	Chequamegon National Forest
Rainbow Lake	6,583	Chequamegon National Forest
Whisker Lake	7,345	Nicolet National Forest
Wisconsin Islands	29	Gravel Island National Wildlife Refuge
Wisconsin Total	**42,323**	
West Virginia		
Cranberry	35,864	Monongahela National Forest
Dolly Sods	10,215	Monongahela National Forest
Laurel Fork North	6,055	Monongahela National Forest
Laurel Fork South	5,997	Monongahela National Forest
Mountain Lake	2,721	Jefferson National Forest
Otter Creek	20,000	Monongahela National Forest
West Virginia Total	**80,852**	
Grand Total	**1,372,155**	

[1]National wildlife refuges are administered by the U.S. Fish and Wildlife Service. National seashores are administered by the National Park Service.
Source: USDA Forest Service 1997b.

Appendix 7–D. Research natural areas (RNAs)[1] in the Northern United States

Research natural area	National forest/State	Year established	Acres
Atwood Ridge	Shawnee/IL	1988	955
Barker Bluff	Shawnee/IL	1990	60
Burke Branch	Shawnee/IL	1991	206
Cave Hill	Shawnee/IL	1990	465
Dennison Hollow	Shawnee/IL	1988	205
Larue-Pine Hills/Otter Creek	Shawnee/IL	1988	2,585
Ozark Hill Prairie	Shawnee/IL	1988	535
Panther Hollow	Shawnee/IL	1988	180
Stoneface	Shawnee/IL	1988	176
Whoopie Cat Mountain	Shawnee/IL	1990	17
Pioneer Mothers Memorial	Hoosier/IN	1944	88
Reas Run	Hoosier/IN	1975	77
Dukes	Hiawatha/MI	1974	233
Grand Island	Hiawatha/MI	1977	59
Horseshoe Bay	Hiawatha/MI	1997	2,065
Newaygo Prairie	Huron-Manistee/MI	1988	180
Nordhouse Dunes	Huron-Manistee/MI	1988	180
McCormick	Ottawa/MI	1971	3,675
Battle Point	Chippewa/MN	1990	329
Clustered Bur Reed	Chippewa/MN	1990	79
Pine Point	Chippewa/MN	1932	1,239
Stoney Point	Chippewa/MN	1990	404
Keeley Creek	Superior/MN	1942	640
Lac La Croix	Superior/MN	1942	973
Marble Lake Lookout	Superior/MN	1988	120
Schroeder	Superior/MN	1988	120
Alpine Garden	White Mountain/NH	1988	100
Nancy Brook	White Mountain/NH	1989	1,385
The Bowl	White Mountain/NH	1931	510
Tionesta	Allegheny/PA	1940	2,113
Cape	Green Mountain/VT	1993	290
Chequamegon Hardwood	Chequamegon/WI	1988	80
McCarthy Lake and Cedars	Chequamegon/WI	1988	64
Memorial Grove Hemlock	Chequamegon/WI	1988	64
Moquah Barrens	Chequamegon/WI	1935	640
Spider Lake	Chequamegon/WI	1988	158
Tucker Lakes Hemlock	Chequamegon/WI	1988	94
Twin Lakes Bog	Chequamegon/WI	1988	36
Bose Lake	Nicolet/WI	1992	81
Grandma Lake Wetland	Nicolet/WI	1991	206
McCaslin Mountain	Nicolet/WI	1991	524
Total			**22,190**

[1]Research natural areas (RNAs) on national forests are protected for the purposes of maintaining biological diversity, conducting nonmanipulative research and monitoring, and fostering education. RNAs help preserve America's natural heritage for future generations. They provide valuable opportunities for monitoring long-term ecological change and comparing the effects of resource management activities against unmanaged controls.

Source: Tyrrell 1999.

Appendix 7–E. Wild and scenic rivers and American heritage rivers in the Northern United States

Wild and scenic rivers	State(s)
Allagash Wilderness Waterway	ME
Allegheny	PA
Au Sable	MI
Bear Creek	MI
Big and Little Darby Creeks	OH
Black	MI
Bluestone	WV
Carp	MI
Clarion	PA
Delaware (Middle)	NJ, PA
Delaware (Upper)	NY, PA
Eleven Point	MO
Farmington (West Branch)	CT
Great Egg Harbor	NJ
Indian	MI
Lamprey	NH
Little Beaver	OH
Little Miami, 2 segments	OH
Manistee	MI
Maurice	NJ
Middle Fork Vermilion	IL
Ontonagon	MI
Paint	MI
Pere Marquette	MI
Pine	MI
Presque Isle	MI
St. Croix	MN, WI
St. Croix (Lower), 2 segments	MN, WI
Sturgeon (Hiawatha NF)	MI
Sturgeon (Ottawa NF)	MI
Sudbury, Assabet, Concord	MA
Tahquamenon (East Branch)	MI
Westfield	MA
Whitefish	MI
Wildcat Brook	NH
Wolf	WI
Yellow Dog	MI

American heritage rivers	State(s)
Blackstone and Woonasquatucket	MA, RI
Connecticut	CT, VT, NH, ME
Cuyahoga	OH
Detroit	MI
Hanalei	HI
Hudson	NY
New River	WV
Potomac	MD, PA, WV
Upper Mississippi	IA, IL, MN, MO
Upper Susquehanna and Lackawanna	PA

Source: USDI National Park Service 2000, U.S. Environmental Protection Agency 1998b.

Appendix 7–F. Forest certification schemes of interest to U.S. forest owners

General features	American Tree Farm System	Forest Stewardship Council		Green Tag Forestry	ISO[1]	Sustainable Forestry Initiative
Sponsor	American Forest Foundation	Scientific certification	Systems SmartWood	National Forestry Association	ISO	American Forest and Paper Association
Scope	National	International	International	National	International	National
Direct costs	Minimal	Moderate to expensive	Moderate to expensive	Moderate	Moderate to expensive	Moderate to expensive
Forester inspections (group certification)	X	X	X	X	X	
Inspection team		X	X		X	X
Third-party verification	Unclear	X	X	Unclear	X	Optional
Region-specific rules	In some areas	In some areas[2]		Proposed	No	No
Status	Established	Established	Established	In development	Established	Established
Current rules and programs to family forests	X	X	X	X		X
Chain of custody		X	X	X		
Eco-label		X	X	X		
General performance measure						
Compliance with existing laws	X	X	X	X	X	X
Requires written forest management plan	X	X	X	X		
Public availability of certification summary		X	X			

[1]International Organization for Standardization
[2]Regional guidelines may be available through either the Forest Stewardship Council or SmartWood and may be different from those presented here.
Source: adapted from Rickenbach 1999.

Appendix 7–F. Forest certification schemes of interest to U.S. forest owners (cont.)

General features	American Tree Farm System	Forest Stewardship Council		Green Tag Forestry	ISO[1]	Sustainable Forestry Initiative
Criteria focus (in addition to applicable laws) X's indicate specific reference to a particular criterion. It does not evaluate the cumulative effects of several criteria together.						
Management and ecology						
Biodiversity (includes endangered species)	X	X	X	X		X
Chemical, pesticide, and herbicide use		X	X			
Forest aesthetics	X					X
Forest health	X	X				X
Landscape		X	X			
Nontimber products (includes recreation)	X	X	X	X		
Protect and enhance fish and wildlife habitat	X	X	X			X
Protection of "special" sites	X	X	X	X		X
Reforestation	X	X	X			X
Silvicultural treatments		X	X			
Stream protection and water quality		X	X	X		X
Sustained yield		X	X			X
Operations						
Road design, construction and maintenance		X	X	X		
Skidding and yarding		X	X			
Slash disposal and product utilization	X	X	X	X		X
Tree felling		X	X			X

[1]International Organization for Standardization
Source: adapted from Rickenbach 1999.

Appendix 7–F. Forest certification schemes of interest to U.S. forest owners (cont.)

General features	American Tree Farm System	Forest Stewardship Council		Green Tag Forestry	ISO[1]	Sustainable Forestry Initiative
Social and economic						
Community relations		X	X	X		X
Documen-tation and monitoring (beyond plan)		X	X	X	X	X
Forestry contractor relations	X	X	X			X
Indigenous rights		X	X			
Landowner tenure, rights, and responsibi-lities		X	X	X		X
Long-term economic viability		X	X	X		X

[1]International Organization for Standardization
Source: adapted from Rickenbach 1999.

Appendix 7–G. Experimental forests and watersheds in the Northern United States

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

Appendix 7–H. U.S. Long-Term Ecological Research (LTER) Program sites

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 affiliations:
[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
Source: LTER Network 2002.

Interrelationships Among Sustainability Criteria

Constance Carpenter[1]

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.

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.

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.

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-

[1]USDA Forest Service, Northeastern Area State and Private Forestry, Durham, NH

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.

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 the spread of 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

Land ownership 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 is critical to meet biodiversity and economic stability needs. 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.

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