1. Forest Resources and Conditions

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The forests of the northern United States support a rich mix of floral and faunal communities that provide inestimable benefits to society. Today's forests face a range of biotic and abiotic stressors, not the least of which may be environmental change. This chapter reviews the compositional traits of presettlement forests and traces the major land use patterns that led to the development of contemporary forested ecosystems. Human impacts have dominated forest development over the last 150 years, so considerable attention is paid to current compositional, structural, and successional traits resulting from these impacts. Estimates of forest carbon storage set the stage for later chapters dealing with environmental factors affecting forest health and resiliency. Resource sustainability is addressed by examining productive capacity (growth) in relation to forest drain components: mortality and removals. Historical information has been gleaned from the literature. Source material for recent trends in timberland area, species composition, stand structure, and net forest drain is from the successive state-level forest inventories conducted by the United States Department of Agriculture (USDA) Forest Service's Forest Inventory and Analysis (FIA) unit. Much of this information was compiled from the FIA's Eastwide Database (Hansen et al., 1992).

Northern Forests in Perspective

The Northern Region covers a wide range of physiographic and climatic regimes, spanning 12 degrees latitudinally and 30 degrees longitudinally, or from Minnesota to Maine in the north and from Missouri to Maryland in the south. The region lies wholly within the Humid Temperate Domain described by Bailey (1994), which includes the Warm Continental Division, portions of the Prairie and Hot Continental Divisions, and a small portion of the Subtropical Division in southeastern Missouri and southern Maryland. Major geophysical relief is found in the Superior Uplands and Central Lowlands of the Lake and Central States; the Ridge and Valley, Appalachian Plateaus, and Adirondacks of the Mid-Atlantic States; and the Green Mountains and White Mountains of New England. For this analysis, the Northern Region is divided into four subregions: Lake States (Michigan, Minnesota, and Wisconsin), Central States (Illinois, Indiana, Iowa, and Missouri), New England (Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont), and Mid-Atlantic (Delaware, Maryland, New Jersey, New York, Ohio, Pennsylvania, and West Virginia).

Of the four regions that make up the United States, the Northern Region comprises 18% of the land area and 23% of the nation's forest area (Table 1.1). What distinguishes this region from the others is its high concentration of people. The Northern Region contains 45% of the population of the United States. Heavily forested areas are common in regions that are not far removed from urban areas with high population densities, such as Minneapolis and Milwaukee in the Lake States, and the urban corridor from Baltimore to Boston along the Atlantic coast. Still, the region's population has a significant impact on forestland for recreational use, timber utilization, and land conversion. Forest fragmentation has become a major concern as urban centers expand into traditionally forest areas. Forest policy of the Northern Region is strongly influenced by the fact that private forestland owners control 8 of every 10 ha of timberland (Powell et al., 1993). The primary reasons cited for private forestland ownership are recreation and esthetic enjoyment. These objectives account for 29% of the region's 3.9 million private owners or 26% of the private forestland (Birch, 1996). Only 1% of the private owners, controlling 19% of the private forest, cite timber production as the primary reason for ownership. These objectives do not necessarily conflict with intentions to harvest, as 35% of the private owners, controlling 61% of the private forest, have expressed intentions to conduct some form of harvest in the next 10 years.

The Northern Region plays an important role in national resource supply, with deciduous forests containing an abundance of high-value oak (*Quercus* spp.), black cherry (*Prunus serotina* Ehrh.), ash (*Fraxinus* spp.),

Table 1.1. Total Land Area, Area of Forestland (Thousands of Hectares), Volume of Growing Stock, Average Annual Gross Growth, Average Annual Mortality, and Average Annual Removals of Growing Stock (Millions of Cubic Meters) by Region and Species Group, Northern U.S., 1997 (Source: Data for Eastern States were Compiled from the USDA Forest Service, Eastwide Database. Data for Western States are from USDA Forest Service, 1992)

Region	Total Land Area	Area of Forestland	Volume of Growing Stock		
			Total	Softwood	Hardwood
North	165,968.3	67,261.0	5,827.7	1,336.5	4,491.2
South	216,314.5	82,802.6	7,117.6	2,933.7	4,184.0
Rocky Mountains	300,366.0	56,547.3	3,121.6	2,873.8	247.8
Pacific Coast	231,896.6	87,664.5	6,163.7	5,507.8	655.8
United States Total	914,545.4	294,275.4	22,230.6	12,651.8	9,578.8

	Average Annual Gross Growth			Average Annual Mortality			Average Annual Removals		
	Total	Softwood	Hardwood	Total	Softwood	Hardwood	Total	Softwood	Hardwood
North	177.2	39.1	138.1	40.1	11.0	29.1	64.0	18.5	45.5
South	357.8	190.6	167.1	62.9	29.1	33.7	260.0	165.2	94.7
Rocky Mountains	81.0	73.3	7.7	19.5	17.1	2.4	23.4	22.5	0.8
Pacific Coast	149.4	128.7	20.6	28.8	24.7	4.0	106.0	101.9	4.0
United States Total	765.4	431.7	333.5	151.3	81.9	69.2	453.4	308.1	145.0

Note: Data may not add to totals due to rounding. Computation of volume, growth, mortality, and removals is based on the merchantable stem of growing-stock trees.

and maple (*Acer* spp.); and coniferous forests of spruce (*Picea* spp.), fir (*Abies* spp.), and white pine (*Pinus strobus* L.) supplying the pulp, paper, and lumber industries. In merchantable volume, the Northern Region has 47% of the nation's hardwood inventory volume and 11% of the softwood inventory. Using gross growth (exclusive of removals) as a measure of productivity, this region averages $2.6\,m^3\,ha^{-1}\,yr^{-1}$ and ranks second behind the Southern Region ($4.3\,m^3\,ha^{-1}\,yr^{-1}$). Compared with other regions, cutting activity is having a relatively minor impact across much of the Northern Region. The ratio of net growth (gross growth minus mortality) to removals is one measure of overall resource sustainability. The Northern Region's ratio of 2.1 ranks second to the Rocky Mountains' ratio of 2.6 with respect to conditions that favor resource sustainability. Some subregions of the Northern Region have more active timber harvesting and are associated with tighter relationships. The ratio for both the Southern and Pacific Coast Regions is 1.1:1.0.

Presettlement Forest

Today's northern forests have evolved in relation to a complex set of natural and anthropogenic influences. Prior to settlement, the major influences on forest character were wind, pathogens, and fire originating from lightning strikes and Native American activity (Seischab and Orwig, 1991). Thus, the presettlement forest was not a continuous stand of immense trees of uniform composition as some envision (Cline and Spurr, 1942). Rather, it contained compositional and structural diversity over a wide range of physiographic and climatic gradients found in this region. Little is known about the extent and composition of the presettlement forest, though some information has been developed from pollen data, land survey records, and studies of old growth forests. Pollen data suggest that prior to settlement, composition was changing toward increasing dominance of pine (*Pinus* spp.) and spruce, and decreasing dominance of birch (*Betula* spp.) and beech (*Fagus grandifolia* Ehrh.) (Russell et al., 1993). The increasing trend for pine and spruce was strongest in the northern hardwood forest. Russell et al.'s finding corroborates Gajewski's (1987) observation that from about A.D. 1450 to the time of European settlement, the abundance of northern tree species was increasing while the more southern species were decreasing, perhaps due to a cooling climate during the period known as the Little Ice Age.

Heavy logging in the Lake States all but obliterated the original "climax" pine–hemlock (*Tsuga canadensis* [L.] Carr.) forests of the region (Weaver and Clements, 1938). Using land office records for counties representative of northern lower Michigan, Whitney (1987) was able to estimate the distribution and composition of precolonial forests. Mixed

pine forests containing red pine (*Pinus resinosa* Ait.), white pine, and jack pine (*Pinus banksiana* Lamb.) comprised about 45% of the area represented by the study area. Oak species were rarely found in the main canopy of mixed pine stands but were common as a suppressed understory component. Pine's predominance was largely due to drought-prone, coarse-textured soils and periodic natural fires. The pure jack pine type, a particularly fire-dependent type, likely accounted for 15% of the original forest. Beech, sugar maple (*Acer saccharum* Marsh.), hemlock, and an associated mix of hemlock, white pine, and northern hardwoods accounted for about 20% of the forest. The remaining 20% was comprised of swamp conifers, including northern white cedar (*Thuja occidentalis* L.), tamarack (*Larix laricina* [Du Roi] K. Koch), and spruce.

Some information on original forest vegetation of the Central States can be gleaned from the work of Blewett and Potzger (1950) and Potzger et al. (1956) in Indiana. Using land survey records, they found that beech and sugar maple constituted at least half of the stems in most of Indiana's townships. Beech often was twice as abundant as sugar maple. Other species of importance were oak, hickory (*Carya* spp.), and ash. Beech–maple forests were common on north-facing slopes and moist upland sites. Beech–maple forests in Indiana were considered a subset of the "mixed mesophytic association" in which beech and maple were the most prominent (Potzger and Friesner, 1940; Braun, 1938). Oak–hickory stands typically occupied south-facing slopes and ridgetops. The composition of oak–hickory forests varied but oaks often were the dominant species. Intermediate slope exposures supported a mixture of species. Bottomland and transient forests occurred infrequently. Although not completely representative of the entire Central States subregion, Indiana contained examples of the major formations of the subregion (Braun, 1950).

In New England, Siccama (1971) found that original forests of northern Vermont contained the same species as today, though in markedly different proportions. The most striking example is beech, which comprised 40% of presettlement composition compared with less than 10% today. In southern New England, Bromley (1935) cited fire as a major factor in restricting the abundance of fire-sensitive species such as hemlock, white pine, and beech. Fire also was important in Maine, where numerous, widespread natural fires played a role in the development of northern conifer, hardwood, and mixed forests. However, the interval between severe disturbances was longer than needed to attain a climax, all-aged structure (Lorimer, 1977). A comparison of Lorimer's estimate of composition with the recent forest inventory for Maine (Griffith and Alerich, 1996) suggests the increased importance of northern white cedar and maple, especially red maple (*Acer rubrum* L.), and the decreased importance of birch and beech. Using numbers of stems as the importance

Table 1.2. New England Presettlement and Current Species Composition as a Percent of Total Forest Composition

Presettlement (%)		Current (%)	
Spruce	21	Spruce	21
Birch	17	Cedar	17
Beech	15	Maple	15
Balsam fir	14	Balsam fir	15
Cedar	12	Birch	10

Note: The current inventory data for Maine was compiled for growing-stock trees at least 12.5 cm in diameter in Aroostok, Penobscot, and Piscataquis Counties—the counties where Lorimer's study sites were located.

value, six genera accounted for at least 10% of total composition (Table 1.2).

Studies of the presettlement forest in the Mid-Atlantic States also have documented differences between precolonial and current composition. Hough and Forbes (1943) found that beech was ubiquitous throughout the Allegheny Plateaus of Pennsylvania. Hemlock–beech and beech–maple were considered as climax associations on most sites. Red maple, yellow birch (*Betula alleghaniensis* Britton), sweet birch (*Betula lenta* L.), white ash (*Fraxinus americana* L.), and black cherry—species of considerable abundance today—were found only locally. Lutz (1930) presented similar findings, citing the low frequency of black cherry and yellow poplar (*Liriodendron tulipifera* L.). Beech and sugar maple were the most widely distributed species in western New York (Seischab, 1990). Seischab and Orwig (1991) supported the view that the presettlement forest contained a large component of "steady state" communities, primarily due to a lack of catastrophic disturbance other than occasional windthrow events.

Land Use History

The process of settlement began along the Atlantic seaboard in the mid-1600s. Colonization began slowly and accelerated gradually, with settlers moving westward and southward. The human population of the Northern Region increased relatively slowly until the mid-1800s when a period of rapid growth began. At first, forests were cleared for cropland to satisfy increased demand for food. On average, every person added to the U.S. population during the 1800s was matched by 1.2 to 1.6 ha of cropland and even more pasture and hayland (MacCleery, 1992). As the population continued to increase, so did demand for wood to build houses and railroads, provide fuel and chemicals for tanning, supply mining props, and support other industries. The advent of rail transportation made vast tracts available, while earlier timbering had concentrated on areas

accessible by water and horse. By the 1920s, conversion of forest to cropland had nearly ceased. Most of the softwood stands were exhausted and the only large reservoirs of virgin hardwood timber in the East were in the Lake States, the southern Appalachians, and the Lower Mississippi Valley (USDA Forest Service, 1920). By this time, most of the forestland in the Northern Region was heavily cut over.

Following the 1920s, northern forests began a period of reestablishment and growth. During the 1930s and 1940s, abandoned farmland provided the source for a new generation of forests. In the 1930s, the Forest Service began conducting forest inventories to track the extent and condition of the nation's forests. Most inventories conducted since that time have documented the steady expansion and improvement of northern forests. The demise of American chestnut (*Castanea dentata* [Marsh.] Borkh.) was one of the major events that occurred during the period of forest regrowth. First documented in 1904, the chestnut blight disease (*Endothia parasitica*) virtually eliminated the species by the 1950s (Harlow et al., 1979).

Today's Northern Forest

The Forestland Base

Today's northern forest encompasses 67.3 million ha (Table 1.3). The Lake States and Mid-Atlantic subregions account for two-thirds of the forestland in the Northern Region. In New England, 81% of the total land base is classified as forest, making it the nation's most heavily forested region. Ninety-five percent of the forestland in the Northern Region is classified as timberland, that is, forestland capable of producing timber crops and which is not reserved from harvesting activity. The timberland estimate is the most useful for analyzing trends because, over time, most FIA inventories have focused on measuring trees on timberland. Some

Table 1.3. Area of Forestland (Thousands of Hectares), Forestland as a Percent of Total Land Area, Area of Timberland, and Percent Change in Timberland Area by Subregion, Northern U.S., 1997 (Source: USDA Forest Service, Eastwide Database)

Subregion	Area of Forestland	Forestland as a Percent of Total Land Area	Area of Timberland	Percent Change in Area of Timberland
Lake States	20,765.8	42	19,464.8	+5
Central States	10,017.3	18	9,566.8	+10
New England	13,078.7	81	12,677.3	no change
Mid-Atlantic	23,399.2	53	22,427.7	+3
North Total	67,261.0	41	64,136.7	+4

Note: Data may not add to totals due to rounding.

reserved forestland in parks, wilderness areas, and urban settings has not been routinely inventoried. The most recent inventories of northern forests indicate that the area of timberland has increased by 4% despite conversion to other land uses. The major source of new forest has been the reversion of retired agricultural land, primarily in rural areas. In areas with relatively high population densities, reversions to forest are offset by conversion of forest to urban, suburban, industrial, and other land uses. The most significant increases have occurred in the Lake and Central States. Timberland in the Mid-Atlantic States increased slightly while there was no change in New England. It is likely that future inventories will show decreases in timberland area as new sources of forestland are scarce and conversion continues.

Ownership

Private forestland ownership is fundamental to understanding forest policy, economics, and management decisions in the Northern Region. Here 80% of the timberland is in the hands of 3.9 million private owners (Birch, 1996). Only 10% of the privately owned timberland is owned by forest industry (defined as those that own and operate a wood-using plant), making the "other private" group the dominant owner in the region (Table 1.4). Often referred to as the nonindustrial private forestland (NIPF) owner, this group is composed of individuals, partnerships, and miscellaneous corporations. Thus, a NIPF owner might be a pension fund investment firm, a retired grandmother, an Indian tribe, a timberland management corporation, or a farmer. A key to understanding NIPF owners is that large numbers of owners control small tracts and a relatively few owners control large tracts. For example, an estimated 3.7 million private owners, or 94% of the private owners, own forest tracts that are smaller than 40 ha; these tracts make up 44% of the private timberland. The remaining 6% of private owners, with tracts larger than 40 ha, control 56% of the private timberland.

Table 1.4. Area of Timberland (Thousands of Hectares) by Ownership Class and Subregion Northern U.S., 1997 (Source: USDA Forest Service, Eastwide Database)

Subregion	All Owners	National Forest	Other Public	Forest Industry	Other Private
Lake States	19,464.8	2,268.6	5,148.6	1,384.7	10,663.0
Central States	9,566.8	693.1	557.9	103.8	8,212.0
New England	12,677.3	407.2	832.4	3,410.3	8,027.3
Mid-Atlantic	22,427.8	594.1	2,327.4	1,240.5	18,265.8
North Total	64,136.7	3,963.0	8,866.2	6,139.3	45,168.1

Note: Data may not add to totals due to rounding.

Although owner objectives are many and complex, private forestland management tends to be custodial, with a minimum of capital investment. Although most native forest types regenerate naturally, it can be difficult to regenerate some preferred species. Also, forest planting is relatively rare in the Northern Region. In 1996, 42,400 ha were planted in the North compared with 709,100 ha in the Southern Region.

In contrast to the Western United States, where public owners control 61% of the timberland, only 20% of the timberland in the Northern Region is in public ownership (Powell et al., 1993). The "other public" class contributes 69% of the public timberland, primarily due to significant state and county ownership in the Lake States. Although the 15 national forests within the Northern Region contribute only 6% of its timberland, they are major suppliers of recreation, timber, and other forest-related benefits.

Forest Type Groups

Data on forest composition, structure, and stage of stand development provide insights into landscape diversity and potential vulnerability to climate change. The FIA reports estimates of timberland area by forest type group, which is an assemblage of specific forest types. For example, the white–red–jack pine group includes the white pine, red pine, white pine–hemlock, hemlock, and jack pine forest types. Although the FIA does not measure stage of stand development directly, the forest type group and stand size class variables are useful indicators. Forest type groups imply some information on successional stage, as pioneer species merge with later successional species and stands convert to other types. Stand size class is a coarse measure of stand structure, as well as a surrogate for stage of stand development. Stand size class is assigned according to the dominance of sample trees by size class, including seedling–sapling (early successional stands), poletimber (midsuccessional), and sawtimber (mid- to late successional). The use of the term "late successional" is somewhat misleading, as stands in the 60- to 80-year range may be of sawtimber size, but are still young with respect to life expectancy. Examples of old growth forest conditions can be found in the North, but are extremely rare.

The major forest type groups of the Northern Region are oak–hickory and maple–beech–birch, accounting for 31 and 30% of total timberland, respectively (Table 1.5 on page 14). Oak–hickory forests are located primarily across the southern tier of the region (Fig. 1.1a in color insert). Oak–hickory is by far the dominant forest type group in the Central States, southeastern Ohio, West Virginia, and the Appalachian Mountains of Pennsylvania. Oak–hickory stands contain some of the highest value hardwood timber in the world. In general, large tracts of oak–hickory have recovered since the logging boom of the turn of the century and are

reaching financial maturity. Sawtimber stands predominate across most of the oak–hickory region (Fig. 1.1b in color insert). Seedling–sapling stands occur infrequently, accounting for only 14% of the oak–hickory timberland. There is concern that a lack of oak regeneration following harvest will result in gradual, long-term declines in oak abundance (Southeastern Forest Experiment Station, 1993).

Timber harvesting and natural disturbances play a role in forest succession. Recent FIA data for West Virginia show that for the 10-year period between inventories, harvesting affected only 24% of the state's timberland (Birch et al., 1992). Clearcut harvests occurred on only 2% of the timberland. Most of the harvesting removed less than 40% of the stand's existing basal area. A preference for harvest of select species also was evident. A study of harvest activity in Pennsylvania produced similar findings (Gansner et al., 1993a). Another concern has been the impact of the gypsy moth (*Lymantria dispar* L.), which has caused significant oak mortality in areas where outbreaks have reached epidemic levels. Chestnut oak (*Quercus prinus* L.) and white oak (*Quercus alba* L.) have been affected more than other species (Gansner et al., 1993b). Most mortality has been in smaller, poorer quality trees. In hard-hit areas such as central Pennsylvania, the entire overstory was killed and young stands of black cherry, red maple, sweet birch, and other species have replaced oak. McWilliams et al. (1995) found that 92% of mixed oak stands in Pennsylvania were adequately stocked with woody species following major disturbance, but that oak stocking was far below predisturbance (including harvesting) levels. Only 16% of the stands were adequately stocked with oak. Yet another concern in Pennsylvania and other areas has been the impact of white-tailed deer (*Odocoileus virginianus borealis* Miller). Populations often exceed 20 per square mile, a threshold that indicates serious impacts on the forest understory. Excessive deer browsing has reduced both the density and diversity of woody understory species (Tilghman, 1989).

Maple–beech–birch, or northern hardwoods, are most common in the northern half of the study region (Fig. 1.2a in color insert). The maple–beech–birch group predominates in northern Pennsylvania, New York, and New England, and is found on cooler, high-elevation sites in the mountains of West Virginia. The Mid-Atlantic and New England subregions account for nearly two-thirds of the northern hardwood stands in the Northern Region. Most of the remaining stands are found in northern Wisconsin and Michigan. As with oak–hickory forests, northern hardwood forests are dominated by older, sawtimber-size stands (Fig. 1.2b in color insert), which make up 51% of the area for this group. Studies of harvest activity for New England and New York indicate many of the same harvest impacts as those found in oak–hickory states. Only about one-third of the timberland studied showed evidence of harvest between inventories (Gansner et al., 1990; McWilliams et al., 1996a).

Color Plate I

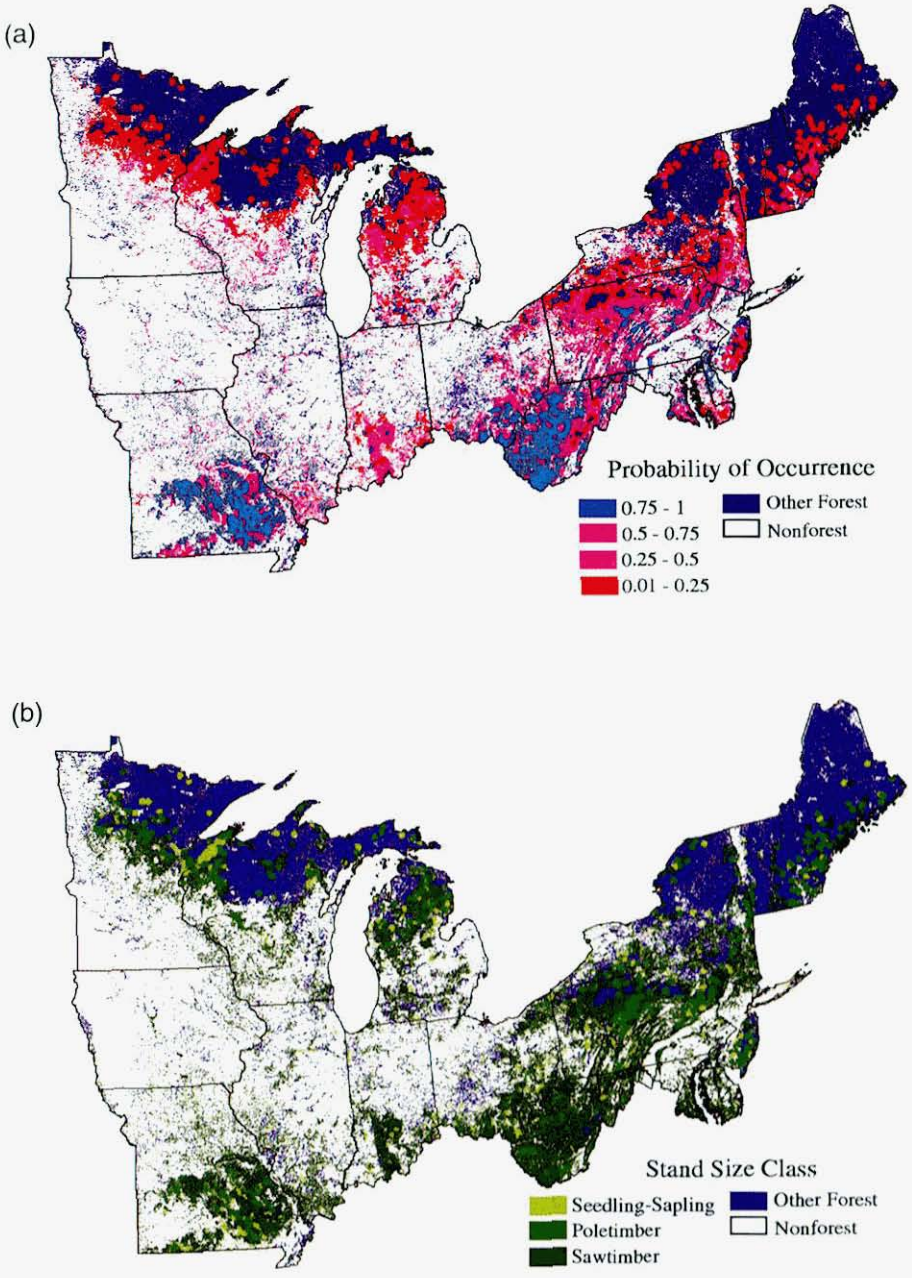

Figure 1.1. Location of forestland, estimated probability of occurrence for oak–hickory forestland (a), and probable distribution of oak–hickory forestland by stand size class (b), Northern Region (excluding southern New England), 1997.

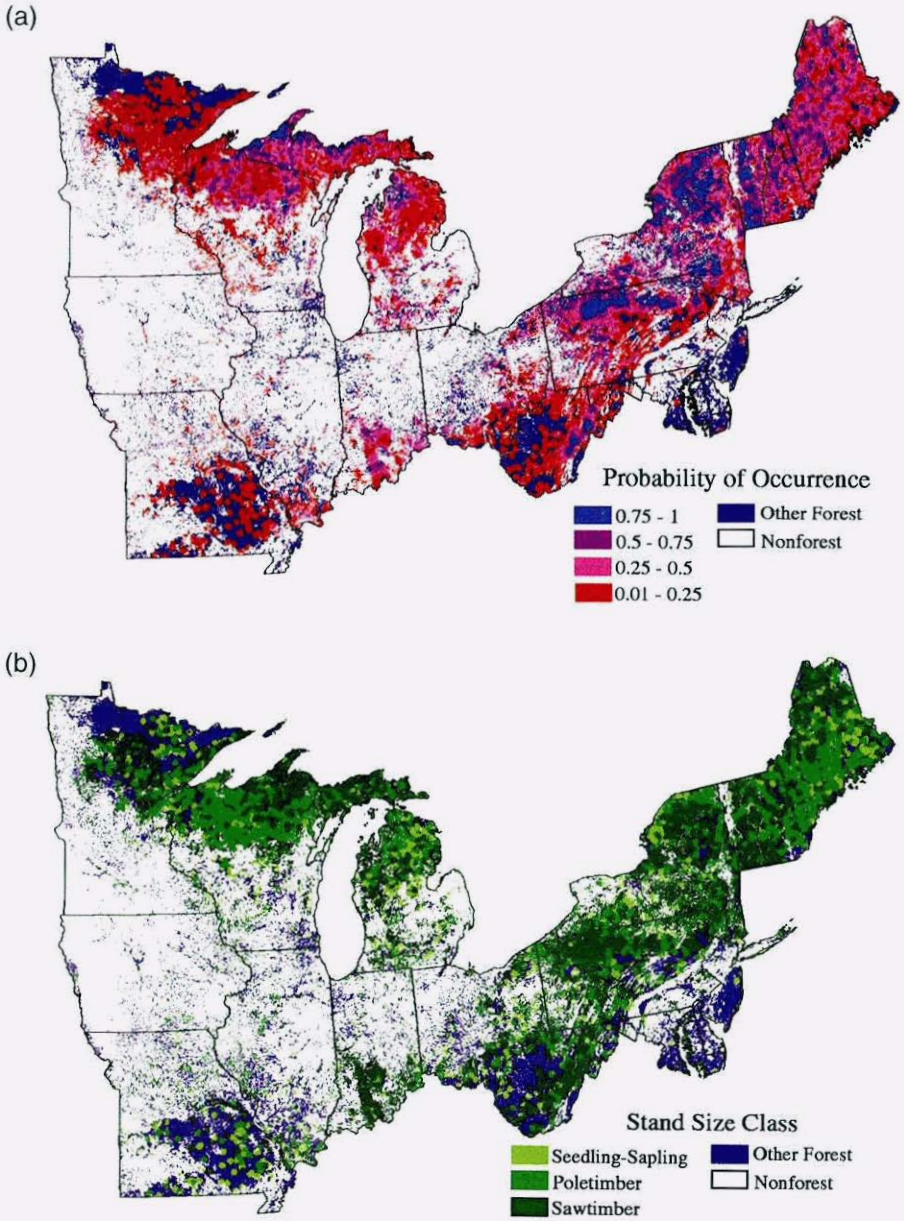

Figure 1.2. Location of forestland, estimated probability of occurrence for maple–beech–birch forestland (a), and probable distribution of maple–beech–birch forestland by stand size class (b), Northern Region (excluding southern New England), 1997.

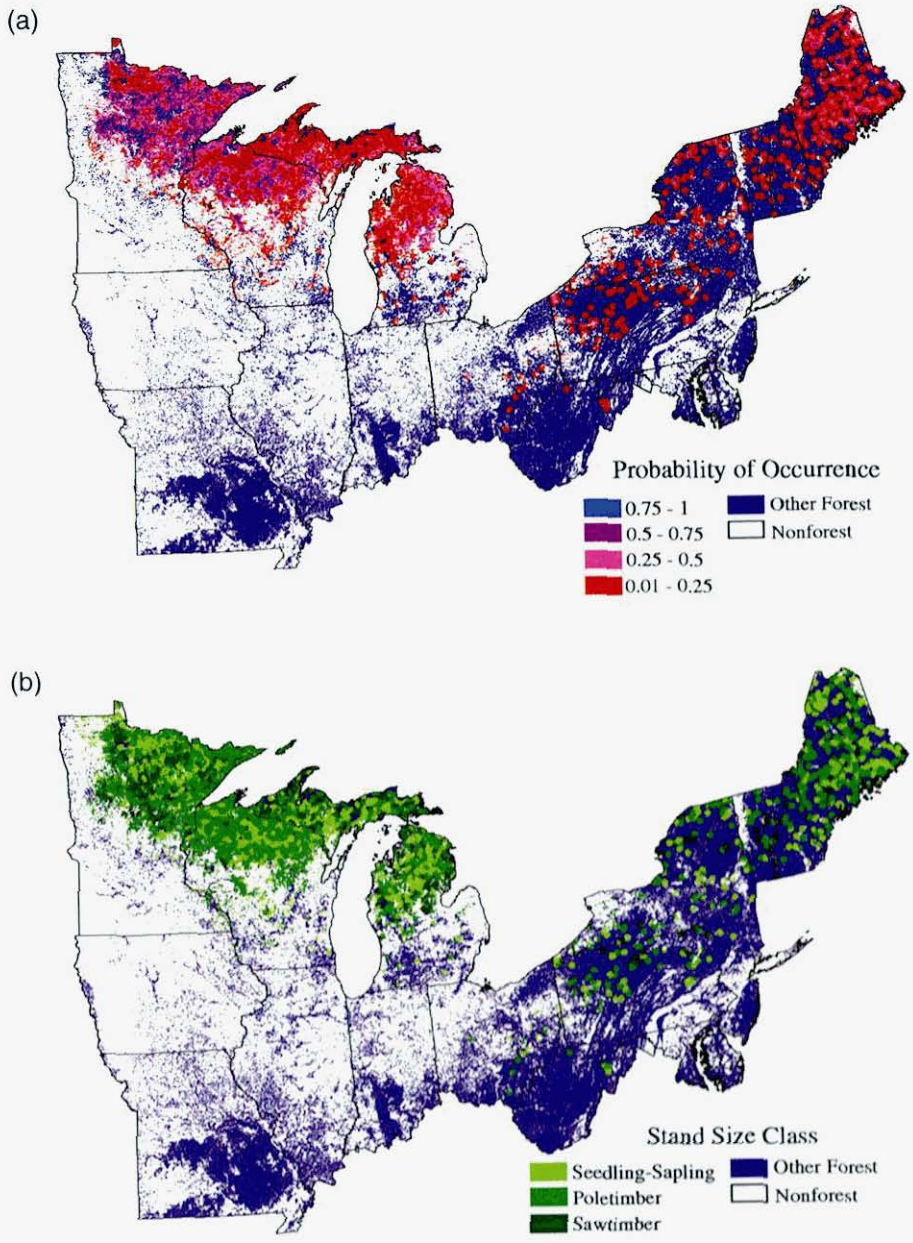

Figure 1.3. Location of forestland, estimated probability of occurrence for aspen–birch forest land (a), and probable distribution of aspen–birch forestland by stand size class (b), Northern Region (excluding southern New England), 1997.

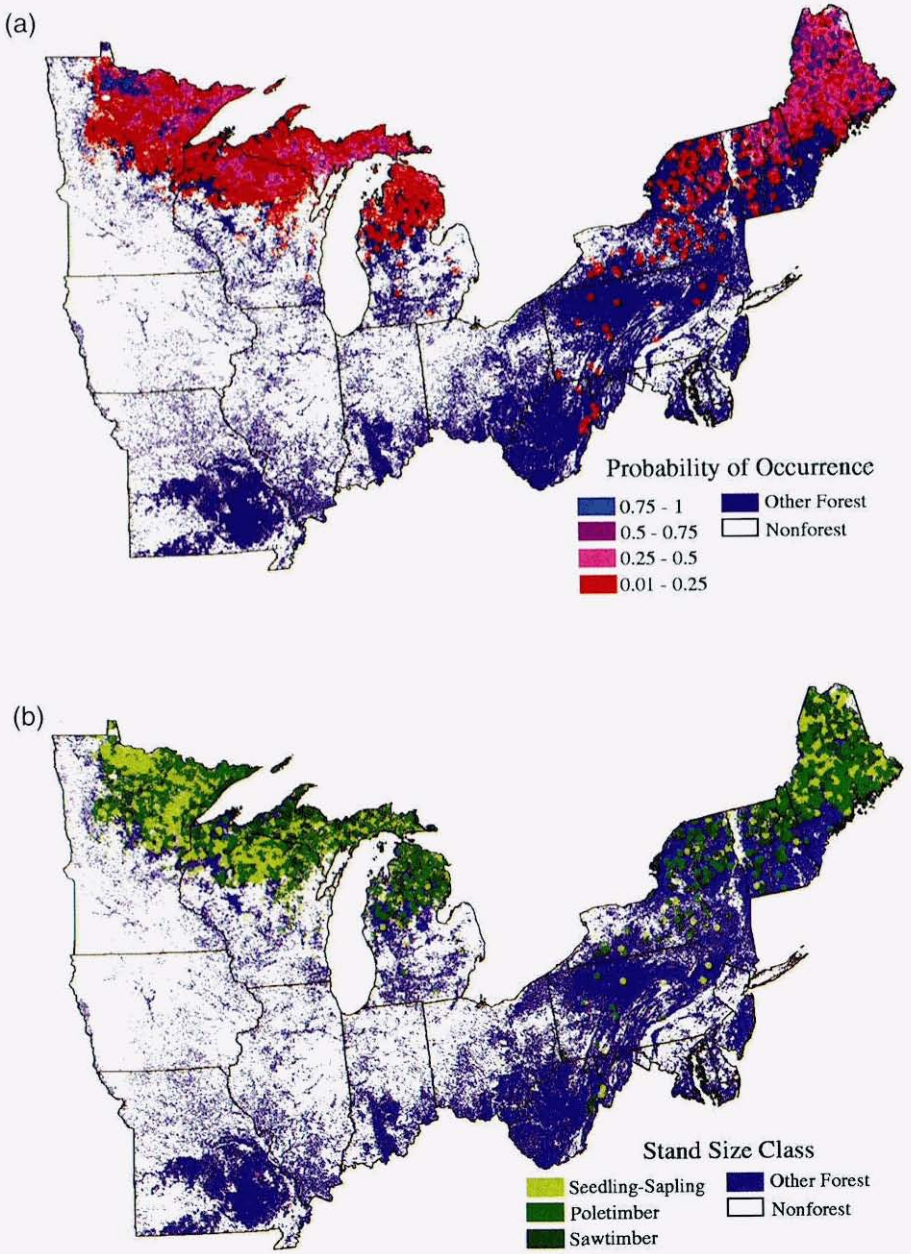

Figure 1.4. Location of forestland, estimated probability of occurrence for spruce–fir forest land (a), and probable distribution of spruce–fir forestland by stand size class (b), Northern Region (excluding southern New England), 1997.

Clearcut harvests were relatively rare compared with partial cutting, and a preference for selecting larger trees of preferred species was shown. These results are supported by a study of harvest disturbance in the Lake States. As northern hardwood stands continue to increase in stocking and size, susceptibility to a range of pests and pathogens also increases. In the Allegheny Plateau region of Pennsylvania, numerous damaging agents have taken a heavy toll in aging northern hardwood stands, particularly sugar maple (McWilliams et al., 1996b).

Aspen–birch is the third most prevalent group in the Northern Region, with 11% of the timberland. More than three-fourths of the aspen–birch forest is found in the northern Lake States, particularly Minnesota (Fig. 1.3a in color insert). The other significant amount of aspen–birch forest is in Maine. Unlike most timberland in the region, aspen–birch is distributed relatively evenly by stand size class with 36% seedling–sapling, 42% poletimber, and 22% sawtimber. Aspen–birch tends to be an early successional type characterized by trees that typically do not become large. In stands that are actively managed, clearcut harvests often perpetuate aspen–birch stands. Aspen–birch also is a common pioneer following major disturbance in other forest type groups. Younger stands of aspen–birch are common throughout the area where aspen–birch is prevalent (Fig. 1.3b in color insert).

Spruce–fir is the fourth most important group, with 10% of total timberland. The spruce–fir group comprises a number of specific forest types, including balsam fir (*Abies balsamea* [L.] Miller), red spruce (*Picea rubens* Sarg.), red spruce–balsam fir, white spruce (*Picea glauca* [Moench] Voss), black spruce (*Picea mariana* [Mill.] B.S.P.), northern white cedar, and tamarack. The group is found primarily in the northernmost areas of the region (Fig. 1.4a in color insert). In Minnesota, spruce–fir is dominated by swamp conifers, which generally are associated with lower stocking levels, growth rates, and disturbance. In Maine, balsam fir, red spruce, red spruce–balsam fir, and northern white cedar are the most common types. The recent inventory of Maine revealed tremendous changes in spruce–fir forests due to infestations of spruce budworm (*Choristoneura fumiferana* Clem.), associated salvage harvesting, and other harvesting to satisfy expanded timber markets. The result was a 20% decrease in spruce–fir timberland (Griffith and Alerich, 1996). Much of this decrease resulted from conversion of spruce–fir stands to northern hardwoods, white–red–jack pine, and aspen–birch. Young stands of spruce–fir are common throughout Maine and the Lake States (Fig. 1.4b in color insert). The distribution of spruce–fir timberland by stand size class is 32% seedling–sapling, 38% poletimber, and 30% sawtimber. A small portion of the red spruce forest type that occurs at high elevations (above 900 m) has been affected by acidic deposition.

The top four forest type groups account for more than 8 of every 10 ha of the timberland in the Northern Region. The remaining timberland is

Table 1.5. Area of Timberland (Thousands of Hectares) by Forest Type Group, Stand Size Class, and Subregion, Northern U.S., 1997 (Source: USDA Forest Service, Eastwide Database)

Forest Type Group	Stand Size Class	North	Lake States	Central States	New England	Mid-Atlantic
Oak–Hickory	Seedling–Sapling	2,838.8	352.3	1,069.7	119.3	1,297.4
	Poletimber	5,791.6	647.1	1,543.2	639.6	2,961.6
	Sawtimber	11,327.7	1,431.5	3,312.4	516.7	6,067.0
	Total	19,958.0	2,430.8	5,925.4	1,275.7	10,326.0
Maple–Beech–Birch	Seedling–Sapling	3,402.4	923.1	455.6	742.0	1,281.8
	Poletimber	6,087.9	1,665.1	321.9	1,920.5	2,180.3
	Sawtimber	9,953.8	2,491.2	908.1	2,295.0	4,259.5
	Total	19,444.2	5,079.3	1,685.6	4,957.5	7,721.6
Aspen–Birch	Seedling–Sapling	2,475.8	1,864.6	3.0	423.9	184.4
	Poletimber	2,956.2	2,208.2	–	549.0	199.1
	Sawtimber	1,535.6	1,340.8	–	132.8	61.9
	Total	6,967.6	5,413.6	3.0	1,105.7	445.4
Spruce–Fir	Seedling–Sapling	2,021.6	1,145.4	–	826.3	49.9
	Poletimber	2,435.6	1,167.0	–	1,163.3	105.3
	Sawtimber	1,879.6	753.5	–	1,000.7	125.5
	Total	6,336.8	3,065.9	–	2,990.2	280.5
White–Red–Jack Pine	Seedling–Sapling	594.4	376.6	9.5	89.3	119.0
	Poletimber	1,115.8	602.8	11.5	266.2	235.5
	Sawtimber	2,774.9	690.6	12.1	1,185.2	887.1
	Total	4,485.1	1,670.0	32.9	1,540.7	1,241.5
Elm–Ash–Cottonwood	Seedling–Sapling	931.0	437.5	150.0	97.3	246.2
	Poletimber	1,210.3	607.1	209.7	146.7	246.7
	Sawtimber	1,873.4	637.8	725.9	86.7	422.9
	Total	4,014.6	1,682.4	1,085.5	330.8	915.8

Oak–Pine	Seedling–Sapling	230.0	–	108.3	25.8	95.8
	Poletimber	517.2	–	129.5	148.2	239.5
	Sawtimber	760.0	–	167.3	214.9	377.7
	Total	1,507.2	–	405.1	388.9	713.1
Loblolly–Shortleaf	Seedling–Sapling	221.0	–	69.8	14.1	137.0
	Poletimber	290.4	–	75.3	27.0	188.1
	Sawtimber	401.9	–	106.4	29.9	265.6
	Total	913.3	–	251.5	71.0	590.7
Oak–Gum–Cypress	Seedling–Sapling	47.8	–	13.7	–	34.2
	Poletimber	68.2	–	20.5	–	47.7
	Sawtimber	192.3	–	101.2	5.9	85.1
	Total	308.3	–	135.4	5.9	166.9
All Forest Type Groups	Seedling–Sapling	12,762.7	5,099.4	1,879.6	2,338.0	3,445.6
	Poletimber	20,473.2	6,897.3	2,311.4	4,860.5	6,403.9
	Sawtimber	30,699.3	7,345.5	5,333.4	5,468.0	12,552.2
	Total	63,935.1	19,342.2	9,524.3	12,666.6	22,401.7

Note: Data may not add to totals due to rounding. Excludes 201.5 thousand hectares of nontyped timberland.

split among the white–red–jack pine, elm (*Ulmus* spp.)–ash (*Fraxinus* spp.)–cottonwood (*Populus* spp.), oak–pine, loblolly (*Pinus taeda* L.)–shortleaf pine (*Pinus echinata* Mill.), and oak–gum (*Liquidambar styraciflua* L.)–cypress (*Taxodium* spp.) groups. These groups often are of local economic importance and valuable for the species diversity and unique habitat they provide. For example, oak–gum–cypress forests are rare in the north (1% of timberland) but represent the northernmost extension of the group, provide critical wetland forest habitat, and contain high-value species such as cherrybark oak (*Quercus falcata* var. *pagodafolia* Ell.).

Biomass and Carbon

Growing concern over increasing concentrations of greenhouse gases in the atmosphere has drawn attention to the impact of forested ecosystems on global climate dynamics. The role of forested ecosystems in accumulating and storing carbon (C) has important ramifications for policies directed toward ameliorating the impact of increasing levels of atmospheric carbon dioxide (CO_2). The most direct method of tracking the amount of C in forested ecosystems is the conversion of existing biomass inventory data. Biomass on northern timberland totals 7.2 billion metric tons (Table 1.6), or roughly 112 tons ha^{-1}. (This estimate excludes the biomass of dead saplings and seedlings.) Nearly 60% of the total biomass is comprised of the nonmerchantable portion of the forest: branches, foliage, stumps, roots, bark, and small and dead trees.

Converting total biomass into C yields an estimate of 3.6 million tons (Table 1.7), or about 56 tons ha^{-1}. The average C content per hectare is relatively constant among Northern subregions. Thus, each subregion's contribution to total C is roughly comparable to the respective area of timberland. The Mid-Atlantic subregion accounts for the highest percentage of total C with 36%, followed by the Lake States (30%), New England (19%), and the Central States (15%).

Of particular interest to policymakers is how current estimates of C compare with historical trends and projections of future changes. Birdsey and Heath (1995) converted historical estimates of biomass to C and projected 1992 biomass estimates 50 years into the future. These estimates included the relative contribution of soils, the forest floor, and existing vegetation (Fig. 1.5). By far, the largest percentage of C stored in northern forests is contributed by forest soils (62%). Changes in total C over the last 50 years have been driven by change in land use from agricultural uses to forest. Although the rate of C flux is projected to decrease in the future, positive fluxes are expected over the next 50 years. As new sources of forest have dwindled over much of the Northern Region, future increases in C are expected to come from the continued growth and maturation of forest vegetation.

Table 1.6. Total Tree Dry Weight Content (Millions of Tons) on Timberland by Subregion, Forest Component, and Species Group, Northern U.S., 1997

	Total	Live Trees of Merchantable Size				Saplings[b]	Dead Trees of Merchantable Size[c]
		Main Stem	Branches and Foliage	Stump and Roots[a]	Bark		
Lake States							
Softwood	475.3	173.2	68.7	73.9	29.7	86.3	43.5
Hardwood	1,650.2	628.2	230.0	227.2	134.9	222.0	207.9
Total	2,125.5	801.4	298.7	301.1	164.6	308.3	251.4
Central States							
Softwood	39.3	16.6	4.8	7.9	2.0	6.2	1.8
Hardwood	1,015.0	410.9	144.7	151.8	77.4	144.4	85.8
Total	1,054.3	427.5	149.5	159.7	79.4	150.6	87.6
New England							
Softwood	518.5	199.0	67.5	91.1	42.9	80.7	37.3
Hardwood	841.6	381.8	71.4	140.1	58.8	154.5	35.0
Total	1,360.1	580.8	138.9	231.2	101.7	235.2	72.3
Mid-Atlantic							
Softwood	284.4	116.3	43.2	53.7	25.9	27.6	17.7
Hardwood	2,331.9	995.2	219.3	420.3	159.9	352.2	185.0
Total	2,616.3	1,111.5	262.5	474.0	185.8	379.8	202.7
North							
Softwood	1,317.5	505.1	184.2	226.6	100.5	200.8	100.3
Hardwood	5,838.7	2,416.1	665.4	939.4	431.0	873.1	513.7
Total	7,156.2	2,921.2	849.6	1,166.0	531.5	1,073.9	614.0

Note: Data may not add to totals due to rounding.
[a] Height of stumps assumed equal to 0.3 m. Stump bark is included.
[b] Includes stem, branches, bark, foliage, stump, and roots.
[c] Includes stem, branches, bark, stump, and roots.

Table 1.7. Total Tree Carbon Content (Millions of Tons) on Timberland by Subregion, Forest Component, and Species Group, Northern U.S., 1997

	Total	Live Trees of Merchantable Size				Saplings[b]	Dead Trees of Merchantable Size[c]
		Main Stem	Branches and Foliage	Stump and Roots[a]	Bark		
Lake States							
Softwood	250.2	90.2	38.7	38.5	15.7	44.4	22.7
Hardwood	839.0	312.8	117.1	113.2	81.8	110.6	103.5
Total	1,089.2	403.0	155.8	151.7	97.5	155.0	126.2
Central States							
Softwood	20.6	8.6	2.7	4.1	1.1	3.2	0.9
Hardwood	507.1	204.6	73.5	75.6	38.8	71.9	42.7
Total	527.7	213.2	76.2	79.7	39.9	75.1	43.6
New England							
Softwood	272.0	103.7	38.0	47.5	22.7	42.0	18.1
Hardwood	421.3	190.1	36.5	69.8	29.5	76.9	18.5
Total	693.3	293.8	74.5	117.3	52.2	118.9	36.6
Mid-Atlantic							
Softwood	150.0	60.6	24.1	28.0	13.7	14.4	9.2
Hardwood	1,163.9	495.6	111.8	209.3	80.1	175.4	91.7
Total	1,313.9	556.2	135.9	237.3	93.8	189.8	100.9
North							
Softwood	692.8	263.1	103.5	118.1	53.2	104.0	50.9
Hardwood	2,931.3	1,203.1	338.9	467.9	230.2	434.8	256.4
Total	3,624.1	1,466.2	442.4	586.0	283.4	538.8	307.3

Note: Data may not add to totals due to rounding.
[a] Height of stumps assumed equal to 0.3 m. Stump bark is included.
[b] Includes stem, branches, bark, foliage, stump, and roots.
[c] Includes stem, branches, bark, stump, and roots.

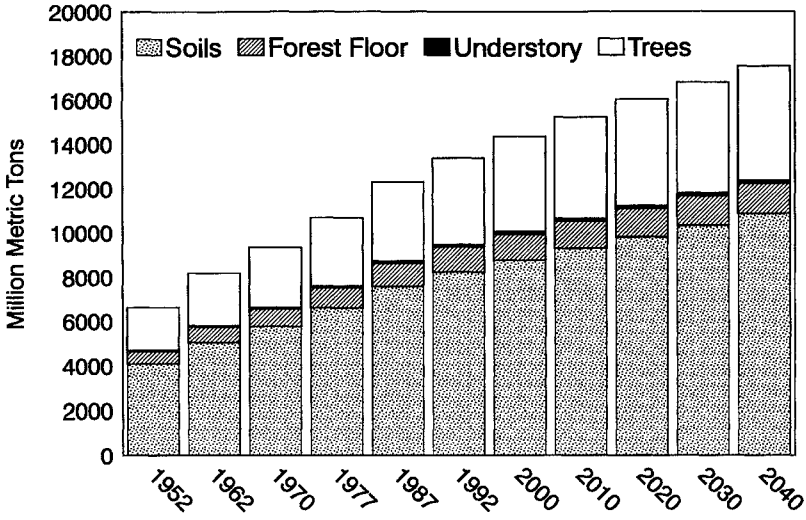

Figure 1.5. Historical and projected estimates of carbon storage (millions of tons) on forestland by forest component, Northern Region, 1997. (Source: Birdsey and Heath, 1995.)

Tree Species Importance

Information on biomass also is useful for describing tree-species richness and heterogeneity across the study region. The FIA inventories identified 143 tree species in the Northern Region, though only 19 species contribute more than 2% of the total biomass (Table 1.8). This diversity has positive implications for the forest's ability to respond to species-specific health concerns and changes in climate. The replacement of gypsy moth–killed white and chestnut oak by red maple and other species is a classic example from recent history. Red maple and sugar maple currently share dominance in the Northern Region, each with 10% of total regionwide biomass. Other important species are northern red oak (*Quercus rubra* L.) with 7% of total biomass, white oak with 6%, and quaking aspen (*Populus tremuloides* Michx.), black oak (*Quercus velutina* Lam.), hickory, and beech with 4% each. Recent inventories within red maple's native range have consistently documented the expansion of this species. Red maples' ability to thrive on a variety of sites (from hydric to xeric) and to regenerate prolifically from sprouts and wind-borne seed has contributed to its expansion. Red maple is now the dominant species in New England and the Mid-Atlantic States, and the third most dominant species in the Lake States.

The Mid-Atlantic subregion had the largest number of tree species tallied (127). The Lake States had the fewest species tallied but the highest number of species with at least 2%, a general indication of an even

Table 1.8. Total Live Tree Dry Weight (Millions of Tons) on Timberland by Species and Subregion, Northern U.S., 1997 (Source: USDA Forest Service, Eastwide Database)

North		Lake States		Central States		New England		Mid-Atlantic	
Species	Weight	Species	Weight	Species	Weight	Species	Weight	Species	Weight
Red maple (*Acer rubrum* L.)	669.2	Sugar maple	242.5	White oak	164.4	Red maple	174.1	Red maple	309.0
Sugar maple (*A. saccharum* Marsh)	654.9	Quaking aspen	199.4	Black oak	118.2	Sugar maple	136.8	Sugar maple	240.6
Northern red oak (*Quercus rubra* L.)	431.6	Red maple	176.8	Hickory spp.	106.6	Red spruce	107.3	Northern red oak	178.8
White oak (*Q. alba* L.)	369.2	Northern red oak	137.7	Post oak (*Q. stellata* Wangenh.)	68.2	Eastern white pine	105.5	White oak	133.8
Quaking aspen (*Populus tremuloides* Michx.)	242.4	Paper birch	114.3	Northern red oak	45.3	Balsam fir	99.6	American beech	130.6
Black oak (*Quercus velutina* Lam.)	239.6	Balsam fir	79.2	Sugar maple	35.0	Eastern hemlock	87.2	Black cherry	127.6
Hickory spp. (*Carya* spp.)	234.1	Northern white-cedar	77.6	American elm	26.4	Yellow birch	80.5	Chestnut oak	122.0
American beech (*Fagus grandifolia* Ehrh.)	232.9	Red pine (*P. resinosa* Ait.)	62.0	White ash	24.3	American beech	75.8	White ash	116.1
Eastern hemlock (*Tsuga canadensis* (L.) Carr.)	209.8	Black ash (*F. nigra* Marsh.)	59.6	Scarlet oak (*Q. coccinea* Muenchh.)	24.2	Northern red oak	69.8	Yellow-poplar	106.1
White ash (*Fraxinus americana* L.)	203.4	American basswood (*Tilia americana* L.)	55.6	Silver maple (*A. saccharinum* L.)	22.5	Paper birch	64.4	Hickory spp.	102.4
Eastern white pine (*Pinus strobus* L.)	198.1	White oak	54.1	Black walnut (*Juglans nigra* L.)	19.5	Northern white-cedar	42.4	Eastern hemlock	96.4
		Black spruce [*Picea mariana* (Mill.) B.S.P.]	51.7	Shortleaf pine (*P. echinata* Mill.)	19.1	White ash	35.8	Black oak	74.5
		Bigtooth aspen (*Populus grandidentata* Michx)	51.3	Bur oak (*Cercis canadensis* L.)	14.4	Quaking aspen	24.4	Eastern white pine	56.1
		Edropline		Eastern redcedar (*Juniperus virginia* L.)	14.2			Sweet birch (*B. lenta L.*)	54.6
		Jack pine (*P. banksiana* Lamb.)	41.8					Scarlet oak	38.4
		Eastern white pine	35.0						

Balsam fir [*Abies balsamea* (L.) Mill.]	185.9	Bur oak (*Q. macrocarpa* Michx.)	33.4						
Paper birch (*Betula papyrifera* Marsh.)	185.8	Yellow birch	33.1						
Black cherry (*Prunus serotina* Ehrh.)	177.6	American elm (*Ulmus americana* L.)	31.9						
Yellow birch (*B. alleghaniensis* Britton)	148.1	Black oak	29.3						
Chestnut oak (*Q. prinus* L.)	128.1	Tamarack [*Larix larcina* (Du Roi) K. Koch]	29.0						
Northern white-cedar (*Thuja occidentalis* L.)	123.5	Black cherry	28.4						
Red spruce (*Picea rubens* Sarg.)	119.9								
Yellow-poplar (*Liriodendron tulipifera* L.)	119.7								
Other species (124)	1,669.3	Other species (61)	250.4	Other species (87)	264.5	Other species (74)	184.3	Other species (112)	527.4
All species	6,543.1	All species	1,874.1	All species	966.8	All species	1,287.9	All species	2,414.4

Note: Species with less than 2% of total live tree dry weight are included as "other species."

distribution. New England had the fewest species tallied (87). The abundance of oak in the Central States is clearly evident, as oaks comprised 45% of the tree biomass in this subregion.

Components of Resource Change

The current growing-stock inventory in the Northern Region totals 5.8 billion m^3, of which more than 75% is in hardwood species (Table 1.9). The Mid-Atlantic contains 41% of the region's inventory, followed by the Lake States (28%), New England (21%), and the Central States (10%). Both timber removals and mortality represent drains on inventory levels. As used here, net growth is equal to gross growth minus mortality.

The growth/removals ratio indicates that northern forests are growing at more than twice the rate of current removals. Positive ratios are apparent for all subregions except New England, where the ratio is 0.8:1.0. The negative drain for New England is driven by the decreases in the softwood resource in Maine. The most favorable conditions for expanding inventories are in the Central States, which has a ratio of 3.1:1.0, followed

Table 1.9. Volume of Growing-Stock, Average Annual Net Growth, Average Annual Removals, and Average Annual Mortality (Millions of Cubic Meters) on Timberland by Subregion and Species Group, Northern U.S., 1997 (Source: USDA Forest Service, Eastwide Database)

Subregion and Species Group	Total	Pulpwood	Sawlogs and Veneer	Other Products
Lake States				
Softwood	449.3	13.8	5.3	4.3
Hardwood	1,173.6	32.4	14.8	11.3
Total	1,622.9	46.1	20.1	15.6
Central States				
Softwood	33.8	1.1	0.2	0.2
Hardwood	552.1	15.2	5.1	4.3
Total	585.9	16.3	5.3	4.5
New England				
Softwood	546.1	5.1	10.1	4.7
Hardwood	673.0	6.2	4.0	1.7
Total	1,219.0	11.4	14.1	6.3
Mid-Atlantic				
Softwood	307.3	8.1	2.9	1.9
Hardwood	2,092.5	55.2	21.7	11.8
Total	2,399.9	63.3	24.6	13.7
North				
Softwood	1,336.5	28.1	18.5	11.0
Hardwood	4,491.2	109.1	45.5	29.1
Total	5,827.7	137.1	64.0	40.1

Note: Data may not add to totals due to rounding.

by the Mid-Atlantic States (2.6:1.0), and the Lake States (2.3:1.0). These findings are not surprising. Except for Maine, all of the recent inventories of northern states have shown increases in inventory volumes. In general, the Northern Region's forests have been undergoing increases in stocking levels and expansion of the number of medium and large trees in the inventory. This is consistent with the notion that these forests are maturing (Schmidt et al., 1996).

Timber Products

Trees that are removed from the existing inventory and converted to wood products provide another form of C storage. The Northern Region traditionally has been a strong supplier of wood products. The value of harvested trees provides incentive for adopting forest practices that enhance a multitude of resources. Projections indicate that demand for wood fiber will increase dramatically in the future.

In 1997, the Northern Region provided 71.6 million m^3 of wood in the form of timber products (Table 1.10). Hardwood species comprised 70%

Table 1.10. Timber Products Output (Thousands of Cubic Meters) by Subregion and Species Group, Northern U.S., 1997 (Source: Miscellaneous USDA Forest Service Timber Product Reports)

Subregion and Species Group	Total	Pulpwood	Sawlogs and Veneer	Other Products
Lake States				
Softwood	7,614.5	5,200.3	2,138.3	275.9
Hardwood	24,537.6	14,443.0	9,732.4	362.2
Total	32,152.1	19,643.3	11,870.7	638.1
Central States				
Softwood	113.1	80.4	18.0	14.7
Hardwood	5,948.6	1,004.9	4,819.4	124.3
Total	6,061.8	1,085.3	4,837.5	139.0
New England				
Softwood	10,969.6	5,998.8	4,671.4	299.4
Hardwood	5,474.3	3,752.7	1,205.2	516.4
Total	16,443.9	9,751.5	5,876.6	815.8
Mid-Atlantic				
Softwood	2,908.1	1,348.3	1,463.3	96.5
Hardwood	13,985.9	3,238.9	10,432.9	314.1
Total	16,894.0	4,587.2	11,896.2	410.6
North				
Softwood	21,605.3	12,627.8	8,291.0	686.5
Hardwood	49,946.5	22,439.6	26,190.0	1,316.9
Total	71,551.8	35,067.4	34,481.0	2,003.4

Note: Data may not add to totals due to rounding.

of the product output. Timber product categories include pulpwood, sawlogs–veneer, and other products. Pulpwood includes woody material that is converted to pulp at the point of first processing. In the northern part of the region, pulpwood is derived primarily from harvests of softwood species and aspen. In the hardwood region to the south, pulpwood is primarily a byproduct of harvesting quality sawlogs and the use of small and poorly formed trees and nonsawlog portions of sawtimber-size trees. Sawlogs and veneer logs are the highest value products derived from northern forests. Some of the other products include fuelwood, pallet wood, and railroad ties.

Nearly all of the wood harvested in the Northern Region is converted to pulpwood, sawlogs, and veneer. Total production is essentially split between these two categories. New England and the Lake States contribute most of the region's softwood products (86%), as well as most of the pulpwood production (84%). Aspen is a major source of pulpwood in the Lake States. The Mid-Atlantic and Lakes States are the primary sources of sawlogs and veneer, each with roughly one-third of total production. Hardwood species make up about three-fourths of total sawlog and veneer products.

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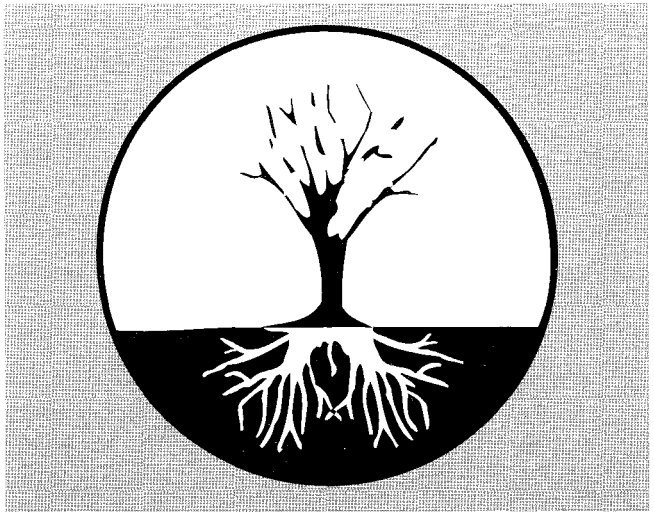
Responses of Northern U.S. Forests to Environmental Change



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