Area Changes for Forest Cover Types in the United States, 1952 to 1997, With Projections to 2050

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A Technical Document Supporting the 2000 USDA Forest Service RPA Assessment

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Authors

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Abstract

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The United States has a diverse array of forest cover types on its 747 million acres of forest land. Forests in the United States have been shaped by many natural and human-caused forces, including climate, physiography, geology, soils, water, fire, land use changes, timber harvests, and other human interventions. The major purpose of this document is to describe area projections of forest cover changes on timberland areas of the United States, in support of the 2000 Resources Planning Act assessment by the USDA Forest Service. Forest area projections differ markedly by region, owner, and forest cover type. Although some regions such as the North are projected to have relatively small percentage changes in common types such as maple-beech-birch (less than 5 percent), others in the South have relatively large projected changes: reductions of 19 percent for upland hardwood on nonindustrial private forest timberlands and 58 percent on forest industry timberlands in the South Central region; and increases in excess of 25 percent for planted pine for both private ownerships in the South. Although the area of softwoods is projected to increase across many regions of the country, especially on forest industry lands, hardwoods will remain the dominant forest type on private lands.

Keywords: Forest land area, forest type transitions, succession, forest cover, timber harvesting, Renewable Resources Planning Act.

Contents

Introduction

We examine land cover changes involving U.S. forests in support of the Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974 (e.g., USDA Forest Service 2001), which directs the USDA Forest Service to conduct a periodic review of the Nation's forest resources. The act requires that an assessment every decade include an analysis of present and anticipated uses; demand for and supply of the renewable resources of forest, range, and other associated lands; and an emphasis on pertinent supply, demand, and price relationship trends.[1] Land cover change has important consequences for the future availability of timber, wildlife habitat, and other renewable resources and, therefore, is a critical component of this analysis. The major purpose of this document is to describe our projections of forest cover changes on timberland areas of the United States, in support of the 2000 RPA assessment (see "Glossary" for definitions of forest land and timberland).

Forest cover changes have important consequences for the future availability of timber, wildlife habitat, forest carbon, and other forest ecosystem goods and services in the United States.

This report focuses on area changes for major forest cover types. Land **cover** is the observed (bio)physical cover on the Earth's surface, e.g., oak-hickory forest. Cover types are related to land **use** changes, but note that land use is the purpose to which land is put by humans, e.g., protected areas, forestry for timber products, plantations, row-crop agriculture, pastures, or human settlements (Di Gregorio and Jansen 1998). A companion general technical report (Alig et al. 2003) documents the projected land use changes for the 2000 RPA assessment.

To better understand forest dynamics, we analyzed historical trends of forest-land area by forest cover type as a basis for making projections of future forest type distributions for private timberlands in the United States through 2050.[2] This report is divided into sections so that the dynamics of each region can be examined independently. Some regions are further divided into subregions so that specific regional attributes can be isolated and comparisons can be made within a region. We use the four RPA regions of the United States: North, South, Rocky Mountains, and Pacific Coast (fig. 1). Table 1 lists the nine RPA subregions within the four regions.

Based on empirical modeling, we provide projections of area changes for forest cover types by RPA region and by decade out to 2050 for major private forest ownership groups. Forest cover changes take place on a fixed total land base, with "forest

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[1] Web sites for the 2000 RPA assessment (USDA Forest Service 2001) are http//www.fs.fed.us/pl/rpa, and http//www.fs.fed.us/pnw/sev/rpa (2001 timber assessment, Haynes 2003).

[2] Historical data pertaining to forest cover type areas sometimes include private and public forest-land estimates, but the majority at regional and national compilation levels are for private timberlands. This limits the foundation for making projections, and in this report we only discuss projections of changes in forest cover type areas on private timberland, but include examination of historical trends on public forest lands within an all-ownership context where data allow.

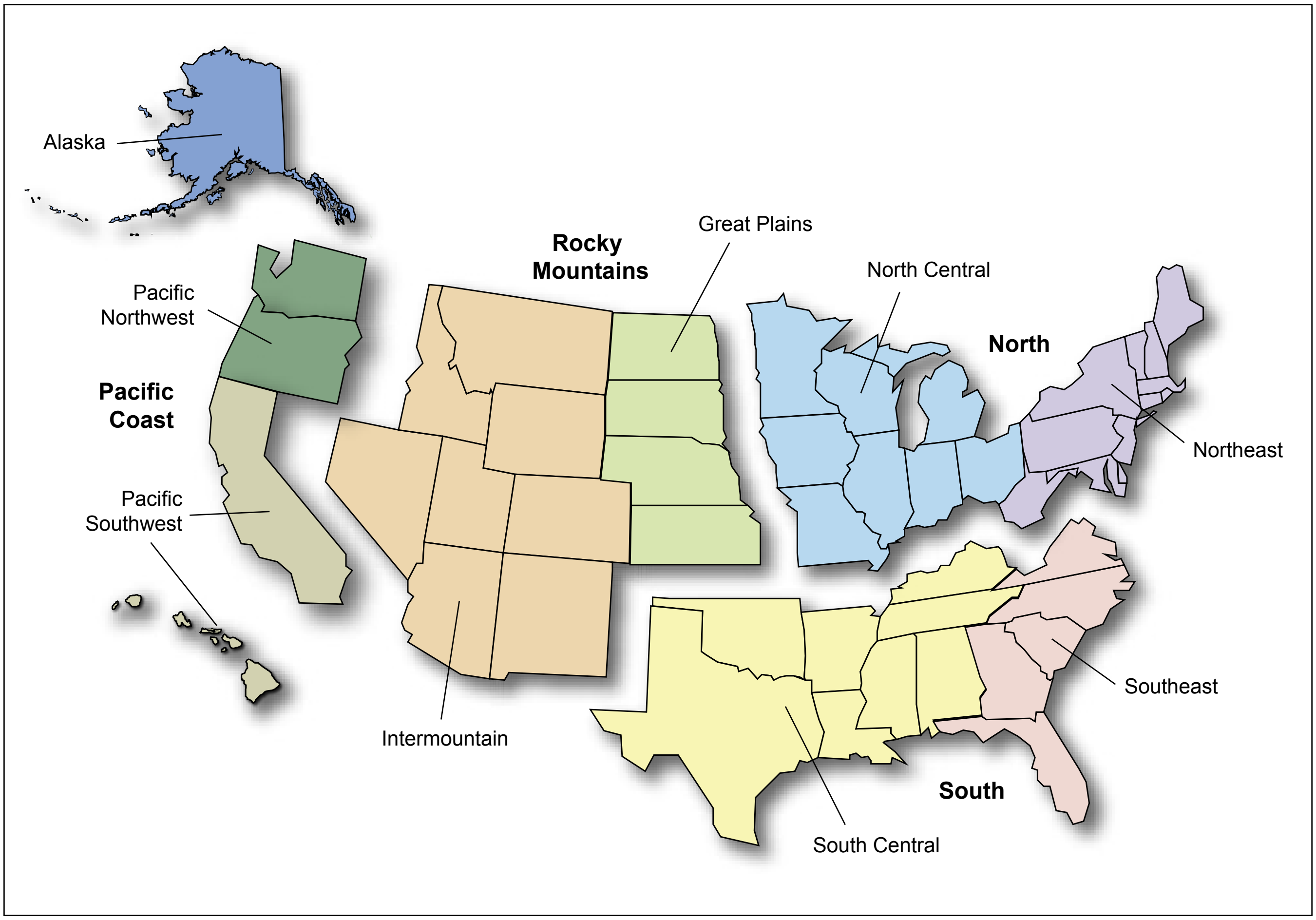

Figure 1—Regions and subregions used in the 2000 Resources Planning Act assessment (USDA Forest Service 2001).

Table 1—Regions and subregions used in the national Resources Planning Act assessment

Region	Subregion	States
North	Northeast	Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia
	North Central	Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, Wisconsin
South	Southeast	Florida, Georgia, North Carolina, South Carolina, Virginia
	South Central	Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas
Rocky Mountains	Great Plains	Kansas, Nebraska, North Dakota, South Dakota
	Intermountain	Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming
Pacific Coast	Alaska	Alaska
	Pacific Northwest	Oregon, Washington
	Pacific Southwest	California, Hawaii

land" as one of the major land use classes. Definitions of land uses and forest cover types can differ by source, and we use definitions and data from the Forest Inventory and Analysis (FIA) units of the USDA Forest Service (e.g., Smith et al. 2001; see "Glossary"). Our 50-year projections of area changes for forest cover types on private timberland are based on the historical data that quantify the areas of the major land use classes over the past 50 years.

We focus on forest cover changes on private ownerships. Private owners control more than 70 percent of U.S. timberland (Smith et al. 2001) and currently contribute more than 90 percent of U.S. timber harvest (Haynes 2003). We use forest industry and nonindustrial private forest (NIPF) ownership classes, where the former class has wood processing facilities (Smith et al. 2001) (see "Glossary" for definitions of ownership classes).

Area changes for forest cover types can differ markedly by ownership and can result from four basic sets of activities: afforestation, deforestation, shifts among forest cover types on retained timberland, and sales or exchanges of land among ownership groups. In contrast to ecological processes, land cover changes and disturbances can differ significantly by type of private ownership. Ownership changes in the timberland base may result in new owners with different land management objectives or different access to types of technology or available resources to invest in forest management. Comparisons of forest type dynamics among owners reflect differences in land management objectives and indicate the differential influence of natural and human-caused management forces.

Area changes for forest cover types on private timberland result from afforestation, deforestation, shifts among forest cover types on retained timberland, and sales or exchanges of land among ownership groups.

We modeled forest type transitions based on analysis of data from remeasured survey plots maintained by the USDA Forest Service FIA units (e.g., Griffith and Alerich 1996). Appendix 1 describes the data and methods used to model the area changes in forest cover types. Methods used in this study are extensions of earlier work for the 1989 RPA assessment (Alig 1985; Alig and Wear 1992; Alig and Wyant 1985; Alig et al. 1990a; USDA Forest Service 1988, 1989). Since the 1989 assessment, additional forest cover data have been collected, and projection models have been refined. In general, forest cover projections have progressed from an expert-opinion basis to systematic empirically based models, as described in appendix 1. Recent data for forest land and timberland are summarized by Smith et al. (2001) and also are provided at http://fia.fs.fed.us/.

Projections of forest type areas are designed to support broad-scale and long-term projections of overall land-base conditions and associated elements of forest ecosystems. An example of linkage to other RPA assessment modeling is interactions with models used in the RPA timber assessment (Haynes 2003). The RPA timber assessment's analysis of the timber situation in the United States, 1952 to

Projections of area changes for forest cover types on private timberland are based on analysis of historical relationships and assumptions about factors affecting future supply and demand conditions, such as population growth and timber prices.

2050 (Haynes 2003), was the fifth in a series of USDA Forest Service indepth analyses of the status and trends of the Nation's timber resources. The forest cover model provides projections of major forest cover areas by region and period, and the timber assessment model feeds back timber harvest amounts and stumpage prices that are used in the forest cover modeling. Current policies are held constant so that we can examine where the current policy trajectory would lead, consistent with the approach in other parts of the RPA assessment. Both the forest cover modeling and other timber assessment modeling rely in part on FIA data. The timber situation report looks at 50 years of historical FIA data, and projects 50 years into the future. The forest cover modeling also provides projections used in other modeling in RPA assessments that addresses an array of resources, including outdoor recreation, fish, wildlife, wilderness, water, range, minerals, and urban forests; however, the primary modeling feedbacks affecting forest cover projections are with the timber portion of the RPA assessment, especially that involving timber harvest, as discussed in this report.

Changes in areas among forest cover types affect a wide range of forest-based goods and services. Examples include wildlife habitat, forest carbon, scenic amenities, and recreation. Such area changes also affect both the nature and volume of timber available from forests. For example, decreases in timber production can occur when commercial species are replaced by noncommercial species. A major consideration in our modeling is that area change projections by forest management type were based on assumptions about the probability that a particular acre will receive a certain type of management and the associated probabilities that an acre so managed will remain in the same forest type or will make the transition to other forest types.

We next discuss the forest cover situation and give projections of area changes for forest cover types on private timberland by RPA region. We then provide a national overview of the projections, drawing upon the RPA assessment findings and interactions with other RPA modeling.

Chapter 1: North

Introduction

The North includes 20 states in the Northeast and North Central subregions of the United States (fig. 1, table 1). This region extends from the Atlantic seaboard in the East to the farmland prairies in the Corn Belt; from the Ohio River, the Appalachian Highlands, and the northern Piedmont in the South to the Canadian border and the Great Lakes in the North. The more northern states of the region have moderately long, relatively severe winters. Annual precipitation is moderate and ranges from 25 to 45 inches; often half of this precipitation comes as snow (USDA Forest Service 1989). Short growing seasons of 100 to 140 frost-free days limit agricultural production.

Forests cover 64 percent of the Northeast and 28 percent of the North Central subregion and most of this land is controlled by nonindustrial private forest ownerships.

Much of this area has been glaciated, and glacial landforms are common. Soils are generally well suited for forests, which are the natural potential vegetation for most of the region; however, high water tables are common in some areas, creating extensive wetland systems. Because much of the North, except for the prairie fringes in the western portions of Iowa, Minnesota, and Missouri, was originally forested, it tends to revert back to forest if disturbed and then allowed to stand idle. In contrast to forests in the West, northern forests tend to have diverse mixtures of tree species, and species mix can differ with climate, soils, and glacial history.

About two-fifths of the North is in forest use, a dominant land use (64 percent) in the Northeast in contrast to that for the North Central region (28 percent). The Northeast is one of the most heavily urbanized parts of the United States, with 12 percent of land classified as "urban" (USDA NRCS 2001). However, states in the Northeast are quite heterogeneous with regard to land use patterns. For example, 88 percent of Maine's land is in forest cover and only 3 percent in cropland, whereas Delaware has 31 percent forest cover and 39 percent cropland. Just 2 percent of West Virginia is classified as urban, whereas 35 percent of New Jersey is so classified.

The North Central subregion has less of its land base classified as urban (7 percent) compared to the Northeast (12 percent). The North Central's Corn Belt contains the states of Illinois, Indiana, and Iowa. Cropland is the dominant land use in this subregion. As in the Northeast, the states of the North Central subregion are quite heterogeneous with regard to land use patterns. For example, Iowa has 80 percent of its land base in cropland and 5 percent in forest. In contrast, Michigan has 24 percent in cropland and 48 percent in forest.

The majority of the forest lands in the North remain in private ownership, most as timberland (figs. 2 and 3). Private owners possess 80 percent of the region's timberland, including most of the region's more productive forest land (fig. 4). The nonindustrial private forest (NIPF) ownership is by far the largest, controlling 71 percent of timberland in the North (Smith et al. 2001).

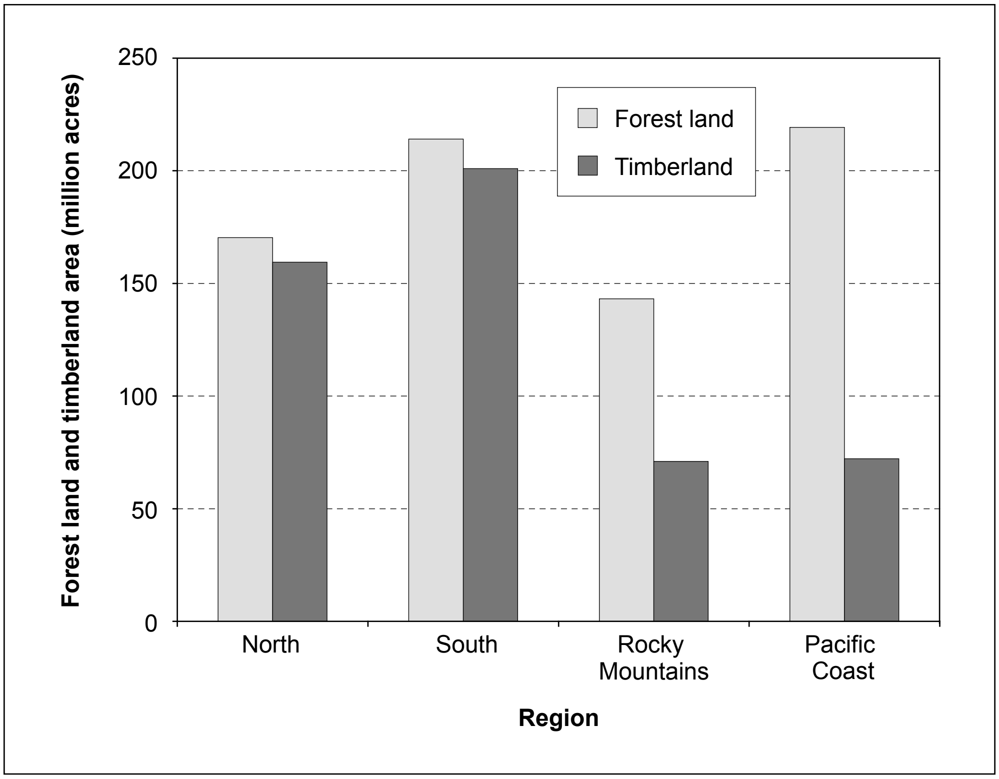

Figure 2—Area of U.S. forest land and timberland by region, 1997 (Smith et al. 2001).

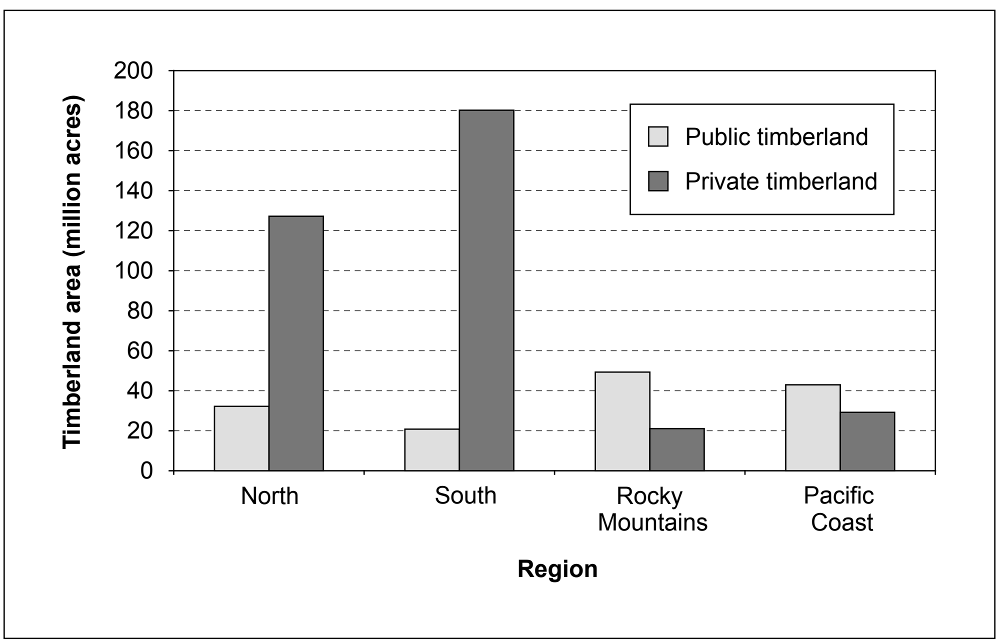

Figure 3—Area of public and private timberland by region, 1997 (Smith et al. 2001).

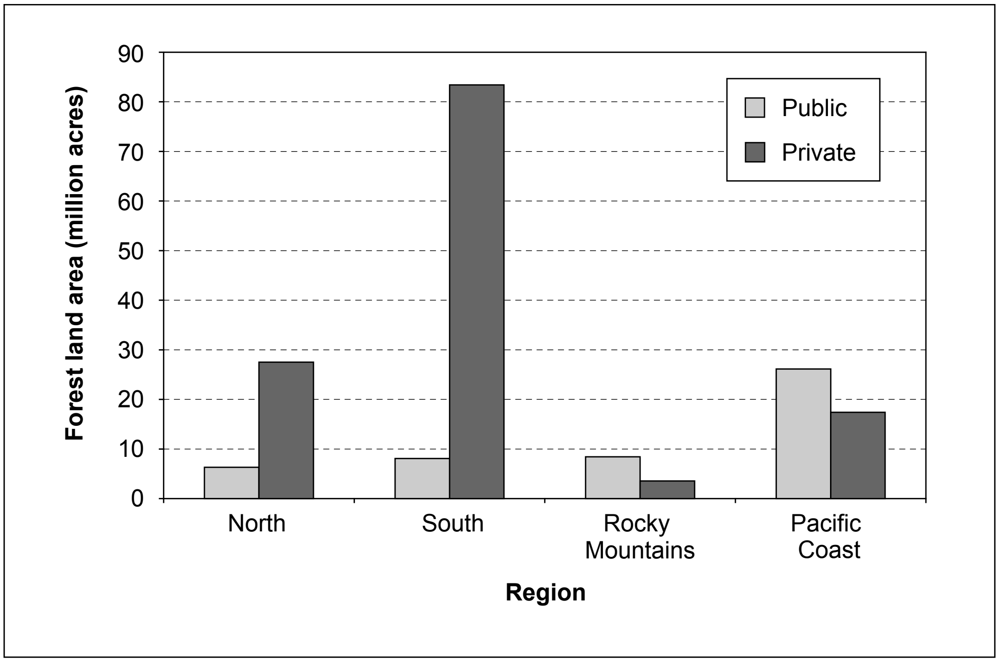

Figure 4—Area of high-productivity forest land by region, 1997, in productivity classes equal to or greater than 85 cubic feet per acre per year (Smith et al. 2001).

The entire region has been heavily disturbed by human activities, with many existing forest stands dating from the late 1800s. Human and natural disturbances exert great influences on forest cover. Historically, fires and windstorms have caused the greatest natural disturbances. Since colonization by European-Americans, human disturbances have escalated in importance. The impetus for these disturbances has evolved from subsistence to profit to conservation and preservation, and the effects have differed based on specific objectives (Stearns 1997, Vasievich and Webster 1997).

Between 1953 and 1997, total area of hardwood forest types in the North increased notably compared to softwood area, with the area of the maple-beech-birch forest type more than doubling.

Forests containing white pine (*Pinus strobus* L.) were the first areas to be logged (often high graded) in response to the country's increasing lumber demands. Eastern hemlock (*Tsuga canadensis* (L.) Carr.) was then harvested for tanneries, and hardwoods for specialty markets were next to be used. In more recent times, aspen (*Populus tremuloides* Mich X.) has surpassed many other species in commercial importance because of its utility in pulp and particleboard production. In addition to commercial uses, the forests of the North have continued to provide important amenities including recreational opportunities.

Forest Cover Situation

Hardwood forest types (e.g., oak-hickory) comprise about 80 percent of total forest area in the North (fig. 5), with about equal percentages in both the Northeast and

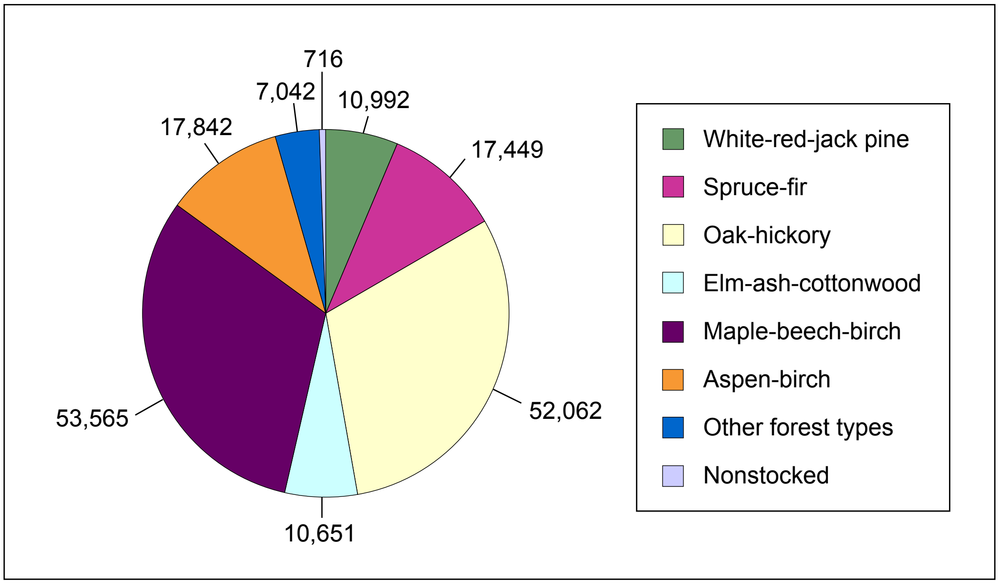

Figure 5—Area of forest land (thousand acres) by forest cover type in the North region, 1997 (Smith et al. 2001).

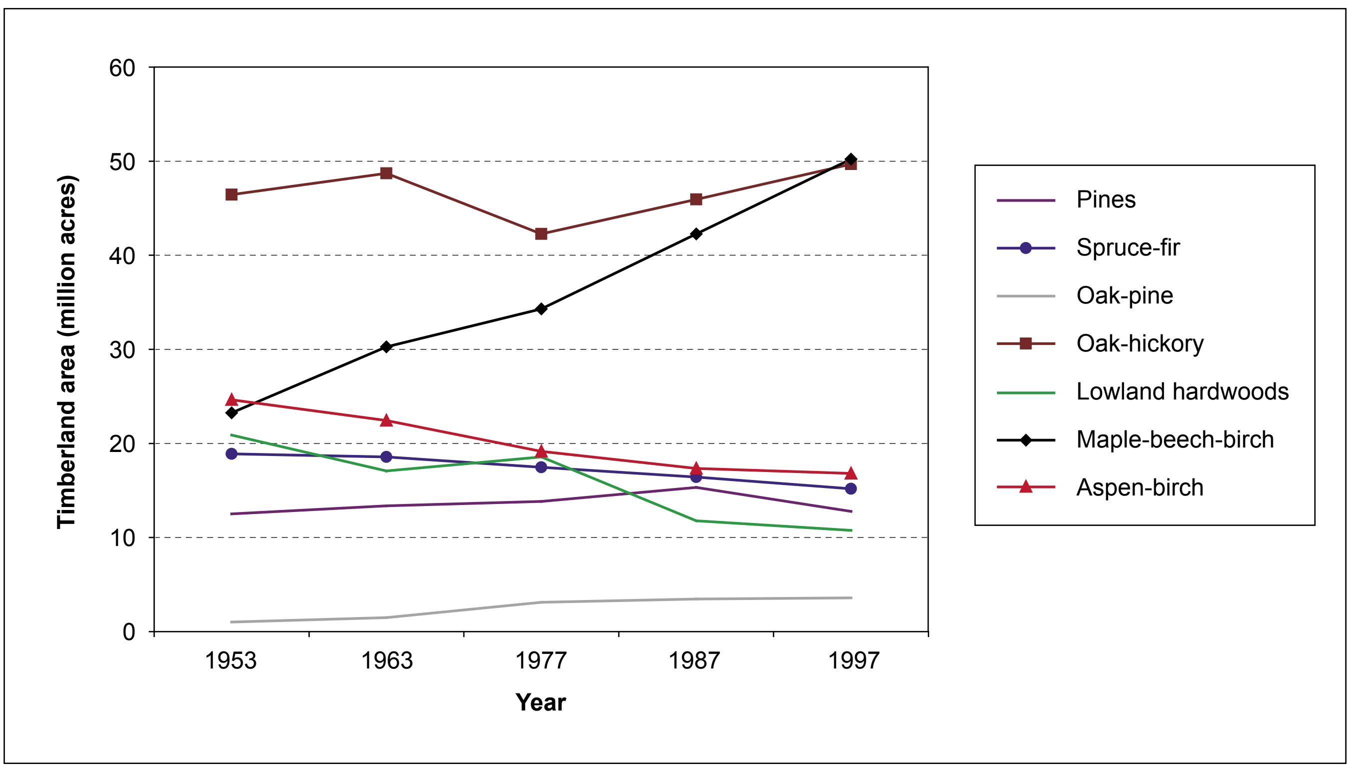

Figure 6—Area trends for major forest cover types on timberland in the North region, 1953 to 1997 (Smith et al. 2001).

North Central subregions. Between 1953 and 1997, total area of hardwood forest types in the North increased notably compared to softwood area (fig. 6). In particular, the area of maple-beech-birch more than doubled, adding 27 million acres; it became the most common type, covering 31 percent of the region's timberland in 1997 (Smith et al. 2001). The large area of oak-hickory also increased, but at a markedly slower rate than for the climax type of maple-beech-birch. The oak-hickory and maple-beech-birch forest cover types cover the largest areas in the North, combining to represent 62 percent or 106 million acres of unreserved forest land (Smith et al. 2001). Generally, the oak-hickory ecosystem grows in a wide band along the southern portion of the area and joins the maple-beech-birch ecosystem to the north (USDA Forest Service 1989).

Area of the mixed type of oak-pine more than tripled between 1953 and 1997, but still only covers less than 3 percent of the region's timberland (fig. 6). Oak-pine is a relatively "unstable" forest type, and slight changes in stand stocking can result in reclassification of the forest type. Increases in total timberland area in the North

Table 2—Area of total timberland in the United States, by softwood and hardwood type groupings and region, 1953–97

Region	1953	1963	1977	1987	1997
			Thousand acres		
Softwoods:					
North	31,396	31,939	31,298	31,745	27,960
South	79,059	77,557	64,573	62,871	63,504
Rocky Mountains	60,997	61,164	55,428	56,035	62,114
Pacific West	58,318	58,035	51,819	50,878	50,369
Total	229,770	228,695	203,118	201,529	203,947
Hardwoods:					
North	116,247	119,970	117,394	120,798	131,071
South	118,141	124,885	129,823	130,798	136,064
Rocky Mountains	5,600	5,756	4,745	5,105	8,796
Pacific West	4,773	4,734	7,566	6,849	8,248
Total	244,761	255,345	259,528	263,550	284,179
Nonstocked timberland:					
North	6,633	4,698	4,754	1,876	404
South	7,346	6,261	5,234	3,599	1,431
Rocky Mountains	3,241	3,280	2,556	1,576	108
Pacific West	4,370	3,242	3,782	814	1,203
Total	21,590	17,481	16,326	7,865	3,146
Total	496,121	501,521	478,972	472,944	491,272

Note: Represents total timberland across all ownerships. Does not include Alaska. Data are from Smith et al. (2001) and are subject to revision. Some row and column totals may not sum exactly due to rounding errors and compilation errors.

The largest area reductions between 1953 and 1997 in the North were for elm-ash-cottonwood and aspen-birch.

since 1977 (table 2) have contributed to the expansion of the oak-pine type, where member species are early to midsuccessional.

The largest area reductions between 1953 and 1997 were for elm-ash-cottonwood, 9.7 million acres, and for aspen-birch, 7.8 million acres. The largest area increase for a softwood cover type was the 1.6-million-acre increase for the white-red-jack pine type. The largest area reduction for a softwood cover type was the 3.7-million-acre decline for the spruce-fir type.

For the most recent historical interval between 1987 and 1997, the North gained more than 5 million acres of timberland, mostly represented now by hardwood types. Pioneer species (e.g., black cherry [*Prunus serotina* Ehrh.] and white ash [*Fraxinus Americana* L.]) naturally regenerated onto abandoned agricultural lands, including former diary farmland and some old-field succession (fig. 7). Other acres were afforested actively with pines, part of the white-red-jack pine type.

Figure 7—Reversion of former agricultural land (e.g., pastureland) to forest has been significant in the North region over the last several decades.

At the same time, other acres were transitioning among seral stages. Between 1987 and 1997, the largest net gains were for the maple-beech-birch (7.3 million acres) and oak-hickory (3.8 million acres) types. Species composition and the successional role of species can differ geographically. For example, most oaks are considered early to midsuccessional species, and although oaks may have an increasing importance going from east to west in the oak-hickory type, much development of oak forests has occurred through a variety of land use and land cover pathways and disturbance patterns. Continuing and overlapping disturbances in the range of oak-hickory forest arise from the frequently high value of the land for agriculture and for developed uses of land near cities. Over the mosaic of the landscape, there can be overlapping disturbance patterns, and seral-stage distribution can be altered markedly by human activities.

The North Central subregion has a slightly higher hardwood cover percentage than does the Northeast. Between 1987 and 1997, the total percentage of hardwood cover types grew slightly in the North. Hardwood types are often the climax species in the North, and successional forces led to the increasing hardwood percentage. Timber harvest in the North, as a potential major disturbance, has not been as prevalent as in other regions, such as the South (Haynes 2003), although exceptions may be northern Maine and parts of the Lake States. This has led to increasingly older forest stands in some cases and a slower regeneration rate when contrasted to the forest cover situation in the South, for example.

The Lake States of Michigan, Minnesota, and Wisconsin (a subset of the North Central subregion) provided roughly two-fifths of 1996 timber harvests in the North (Smith et al. 2001), with most coming from private timberlands. In 1997, maple-beech-birch and aspen-birch were the most abundant forest cover types on private timberlands in the Lake States. Aspen-birch covered more than 7 million acres and about 90 percent was located on NIPF lands. For forest industry, the three forest types with the largest areas are maple-beech-birch, 44 percent; spruce-fir, 28 percent; and aspen-birch, 11 percent (Smith et al. 2001).

In general over the historical period, greater absolute and relative changes in the Lake States have been on NIPF timberlands rather than on forest industry timberlands. The NIPF ownership also has been the most affected by land use changes. The changing nature of agriculture and conversions of forest land to developed uses have been major factors in forest area changes in the North (Mauldin et al. 1999a, 1999b; Plantinga et al. 1999). Some Northern states have had an increase in forest area in recent decades, with most of the increase linked to a decrease in agricultural area, particularly in the dairy sector (Mauldin et al. 1999a, 1999b). Pastureland area in all three Lake States has declined since 1953, with a shift from pasturing to intensive cropping as the primary method of growing feed for livestock. As in the Northeast, many abandoned pasturelands have reverted naturally to forests. In the North, the largest gain in forest cover by type has been the 8-million-acre gain in maple-beech-birch between 1987 and 1997 (Smith et al. 2001), with the gain primarily on NIPF timberlands.

In the Northeast, maple-beech-birch and oak-hickory were the most abundant forest covers in 1997. Maple-beech-birch covered more than 10 million acres of land, 86 percent of that owned by NIPF owners. For the NIPF ownership in the

Northeast, the three forest types with the largest areas are oak-hickory, 36 percent; maple-beech-birch, 32 percent; and aspen-birch, 8 percent.

Maine provided more than one-third of the Northeast's timber harvest in 1996 (Smith et al. 2001). Slightly more than one-half of 1996 timber removals in Maine were softwoods, slightly higher proportionately than timberland area in softwood cover types (Griffith and Alerich 1996). Spruce-fir is the main softwood type in Maine, covering about 35 percent of the state's timberland. The northern hardwoods type replaced the spruce-fir type as the most common forest cover type, as its 6 million acres cover 38 percent of Maine's timberland (Griffith and Alerich 1996). A major factor has been the transitions of spruce-fir stands to northern hardwoods following harvest of the spruce-fir type. These changes have almost all been on private timberlands, which represent 96 percent of the Maine total and which have seen significant ownership shifts in recent decades (Plantinga et al. 1999). In contrast to earlier trends, since the 1980s, NIPF timberland area in Maine has increased while forest industry timberland area has declined.

Dominant projected changes for forest cover in the North are decreases in the areas of spruce-fir and aspen-birch and increases in the areas of lowland hardwoods and maple-beech-birch.

Projections

Dominant projected changes for forest cover on private timberland in the North are decreases in the areas of spruce-fir and aspen-birch and increases in the areas of lowland hardwoods (including red maple-dominated forest types, fig. 8) and maple-beech-birch. Projected area changes for hardwood forest cover types are largely based on a continuation of recent trends, whereas softwood cover types are projected to diverge somewhat from historical trends. Overall, the trend is toward a higher percentage in hardwood types relative to softwood types (table 3).

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Figure 8—Area of red maple has increased significantly in parts of the Northeast subregion in recent decades.

The projected changes vary across the region, with the losses of spruce-fir and aspen-birch in the Northeast (e.g., Maine, Vermont, New Hampshire, and New York) and the Lake States (i.e., Michigan, Minnesota, and Wisconsin), respectively (figs. 9–12). Most of the changes are projected for the NIPF ownership, which contains a large majority of the timberland in the region. Most of the changes on forest industry lands are projected

Table 3—Projected area of private timberland in the United States by softwood and hardwood type groupings by region, 1997 to 2050

Timberland type and region	1997	2010	2020	2030	2040	2050
			Thousand acres			
Softwoods:						
North and Rocky Mountains	36,363	35,190	34,354	33,544	32,787	32,209
South	56,105	63,744	68,014	70,990	72,462	73,103
Pacific Coast	18,613	18,427	18,224	18,053	17,929	17,871
Total softwood area	111,081	117,361	120,592	122,587	123,178	123,183
Hardwoods:						
North and Rocky Mountains	112,183	113,657	113,049	111,469	109,399	107,690
South	122,635	114,708	109,773	106,407	104,214	102,830
Pacific Coast	5,806	5,542	5,403	5,290	5,200	5,140
Total hardwood area	240,624	233,907	228,225	223,166	218,813	215,660
Total private timberland area	351,705	351,268	348,817	345,753	341,991	338,843

Note: Does not include nonstocked timberland. Some column totals are subject to rounding errors and compilation errors.

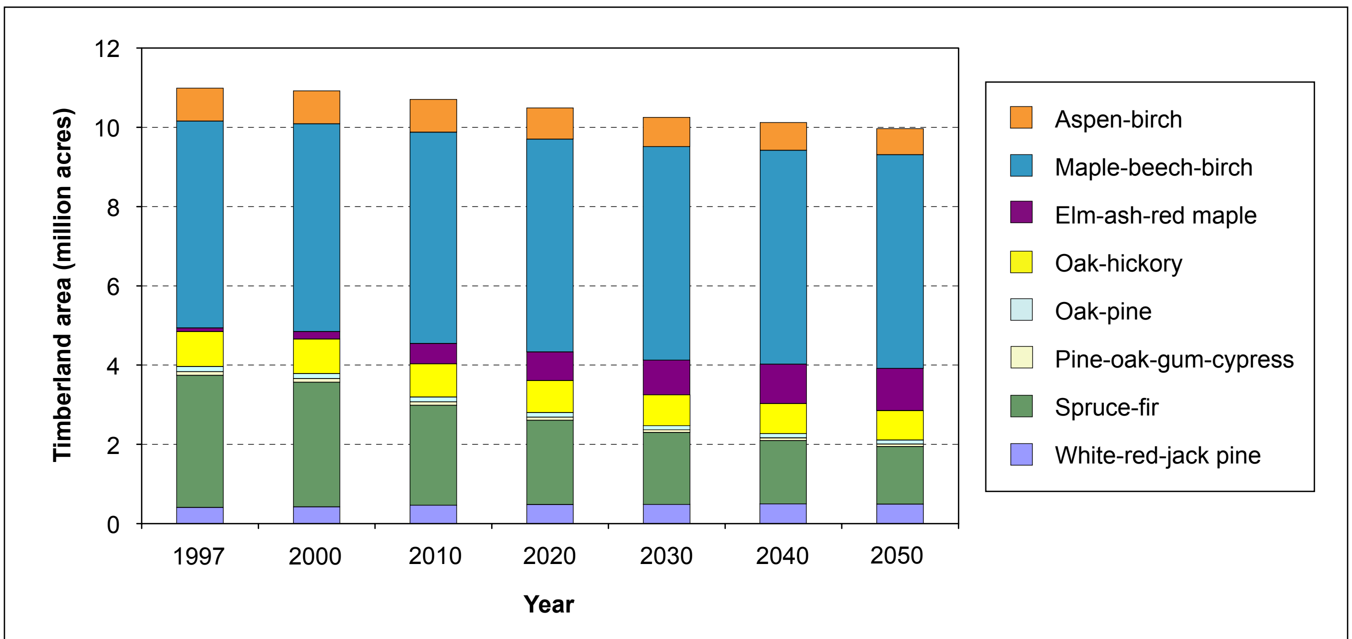


Figure 9—Projected area changes for forest cover types on forest industry timberlands in the Northeast, 1997 to 2050.

decreases, with the exception of the area of white-red-jack pine, which is projected to increase by nearly 40 percent over the next 50 years.

Within the region, the forests of the Lake States are expected to continue to provide a substantial proportion of the region's timber harvest and have the larger relative changes in areas of forest covers. The projected trends of the hardwood forest

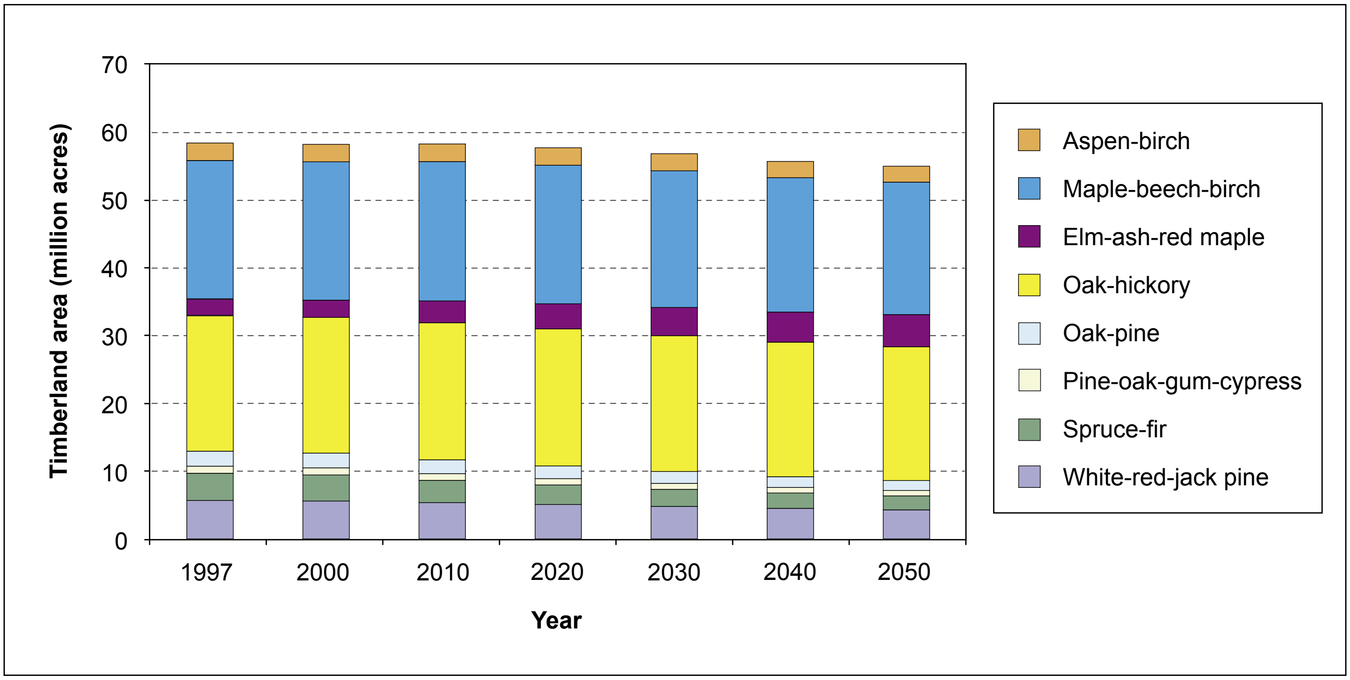


Figure 10—Projected area changes for forest cover types on nonindustrial private forest timberlands in the Northeast, 1997 to 2050.

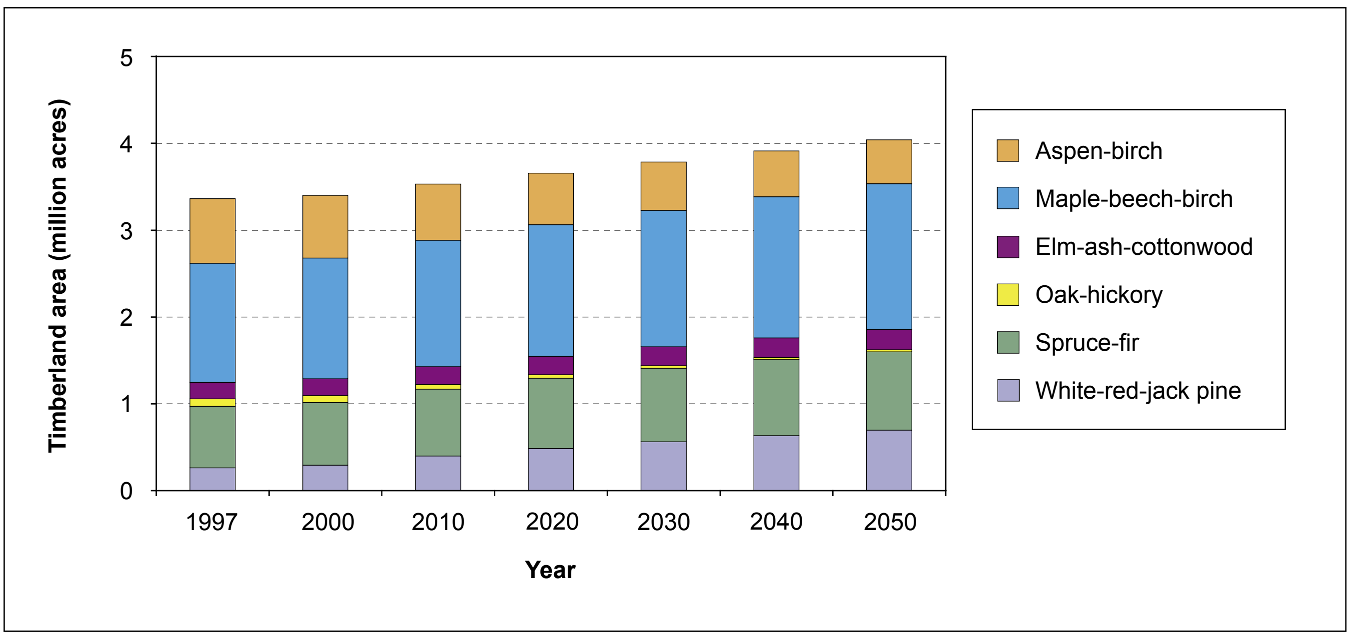


Figure 11—Projected area changes for forest cover types on forest industry timberlands in the Lake States, 1997 to 2050.

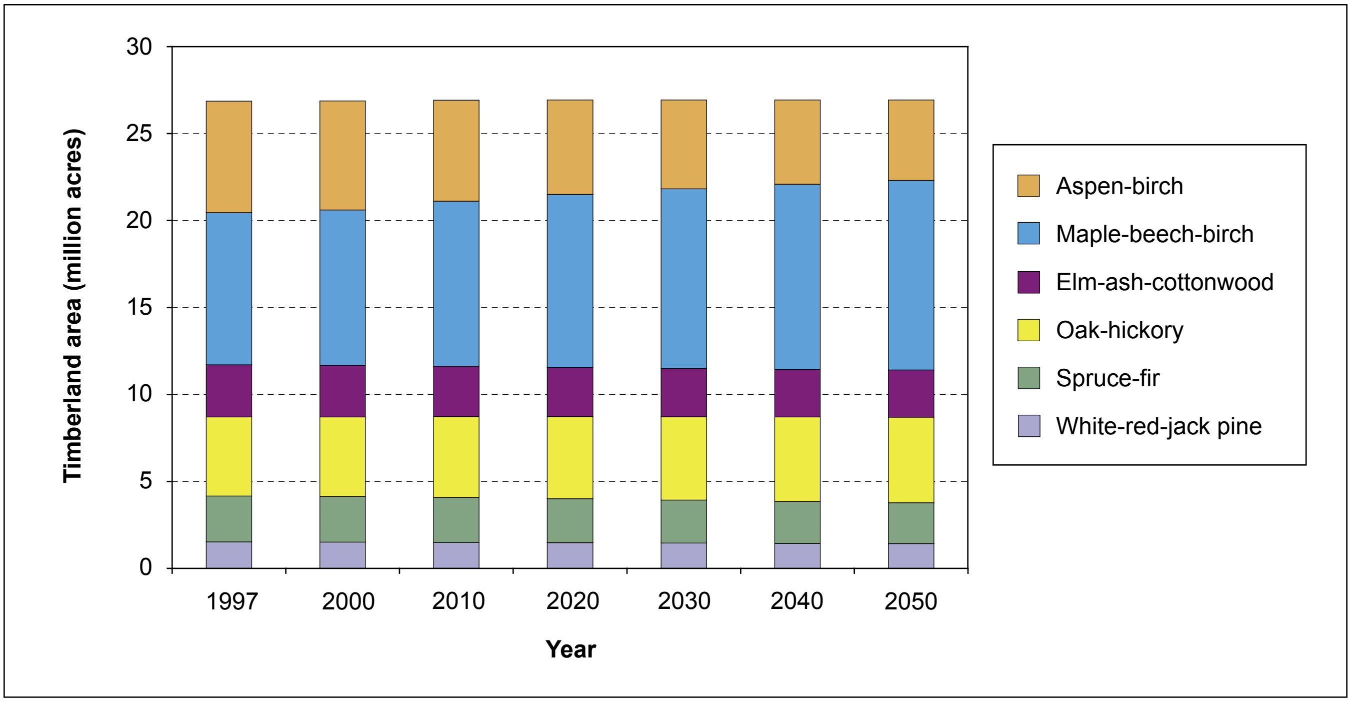


Figure 12—Projected area changes for forest cover types on nonindustrial private forest timberlands in the Lake States, 1997 to 2050.

covers are largely consistent with historical trends, whereas the projected softwood trends are somewhat divergent from historical trends. On private timberlands in the Lake States, the changes in the forest cover areas are projected to range from decreases of 19 percent to increases of 17 percent between 1997 and 2050.

On NIPF timberlands in the Lake States, maple-beech-birch is projected to increase by approximately 1.7 million acres, a 19-percent increase (fig. 12). Most of this increase is from oak-hickory, aspen-birch, and elm-ash-cottonwood forest covers. Elm-ash-cottonwood is the only other NIPF forest cover projected to have a net increase (98 thousand acres, 3-percent increase). Of the decreasing forest covers, white-red-jack pine and spruce-fir forest covers are projected to have the largest relative losses, 22 and 23 percent, respectively, but oak-hickory and aspen-birch also are projected to have substantial area decreases.

In the Northeast, the area of elm-ash-red maple forest is projected to increase.

Notable projected changes are an increase in the area of elm-ash-red maple forests in the Northeast and decreases in the areas of spruce-fir in the Northeast and aspen-birch in the Lake States. The increase in elm-ash-red maple is primarily due to the large influx of red maple in the region. The projected decrease in spruce-fir is related to the large areas infected by insect pests (e.g., spruce budworm [*Choristoneura occidentalis* Freeman]) that were recorded in the data used to develop the projection model. The loss of aspen-birch has largely been the result of insufficient regeneration opportunities for this early successional forest type.

Timber harvests on forest industry and NIPF lands in the North have been at or below timber growth for some time (Haynes 2003), causing timber inventories to be stable or rising. Timber harvests are projected to increase on NIPF timberlands, driven by expansion in both sawtimber and pulpwood uses. At the same time, NIPF timberland owners in the region are increasingly motivated by objectives other than timber harvest and revenue generation in managing their lands. A disinclination to harvest timber is related in part to fractionation of the timberland base (Alig et al. 2000b), growing diversity of types of owners (King and Butler, in press), and to the declining importance of timber harvest revenues in the income of forest landowners. As a result, NIPF hardwood inventory will continue to rise.

On forest industry timberlands in the Lake States, the white-red-jack pine forest cover is projected to have the greatest relative and absolute changes with a projected increase of 314,000 acres or 120 percent between 1997 and 2050 (fig. 11). Maple-beech-birch is the only other forest cover to have a projected increase, but the increase is only projected to be 1 percent or 17 thousand acres. Of the decreasing forest covers, aspen-birch is projected to have the most substantial decrease with a loss of 193,000 acres or 26 percent. Oak-hickory is also projected to have a rather substantial decrease with a projected loss of 19 percent of its 1997 area or 73,000 acres.

The maple-beech-birch forest cover is projected to have the largest area increase in the Lake States.

The maple-beech-birch forest cover is projected to have the largest area increase in the Lake States. This increase is on NIPF lands and is the result of a combination of transitions following both final and partial harvests and natural succession. Aspen-birch, elm-ash-cottonwood, and oak-hickory have only moderate partial timber harvest probabilities; approximately 1 percent of each of these forest covers is projected to be partially harvested. However, they have relatively high propensities, 25 to 30 percent, to transition to maple-beech-birch following these partial timber harvests. At least part of this high-transition propensity is due to maple-beech-birch being a relatively diverse forest cover compared to the other forest covers, and partial timber harvests will release the more shade-tolerant species that are characteristic of this forest type. Maple-beech-birch is a later successional forest type, consistent with higher probabilities of transition to this cover type if no harvest occurs over a remeasurement period.

Final harvests of timber in the Lake States lead to the highest probabilities for transitions among forest cover types. Following a final harvest on private lands, the resultant forest cover is expected to be the same as the previous forest cover in most circumstances (55 percent on average), but this differs greatly among forests types and owners. On forest industry lands, maple-beech-birch, spruce-fir, elm-ash-cottonwood, and white-red-jack pine forest covers are more likely to transition to a different forest cover following a final harvest than to stay the same forest cover. Aspen-birch and oak-hickory are the forest covers that are most likely to result from a transition. On NIPF lands, white-red-jack pine, oak-hickory, and spruce-fir forest covers are more likely to transition to other forest covers than to remain the same forest cover following a final harvest. Aspen-birch, maple-beech-birch, and oak-hickory are the most common forest types to result from transitions on NIPF lands.

On average, 78 percent of the private timberland in the Lake States that received partial timber harvests were projected to remain the same forest type following this management activity, with this average value being slightly lower for NIPF lands (75 percent) than for forest industry lands (81 percent). Aspen-birch, elm-ash-cottonwood, and oak-hickory have the highest propensities to transition on NIPF lands, whereas aspen-birch and spruce-fir have the highest transition probabilities on the forest industry lands. Elm-ash-cottonwood and aspen-birch were expected as the most common fates of partially harvested acres on both NIPF and forest industry timberlands that transition among forest cover types. If no harvests occur, the probabilities of transitions are very low within the 13-year time step. On forest industry lands, an average of 2 percent of the forest covers are expected to transition to another forest cover in the absence of harvest activities; these values ranged from 1 to 3 percent, disregarding the nonstocked lands. An average of 1 percent of the NIPF timberlands would transition without harvests, with a range of 1 to 2 percent. Elm-ash-cottonwood and aspen-birch have the highest propensities to transition to another forest cover.

One resource issue identified when considering the future outlook in a Lake States forest resource study (Vasievich and Webster 1997) is the declining available aspen resource. This relates to investments in processing capacity in the region. However, regional capacity growth for aspen-based industries like oriented strand board has slowed in recent years (Ince 2000). Over the entire timberland base in the Lake States, timber growth exceeds harvest by a significant amount, and although the amount of harvest of timber has increased over the past 40 years, forest growth has increased more, leading to more timber inventory (Smith et al. 2001). Harvest is projected to remain below growth on NIPF timberlands in the North, and industrial timber harvest at or just below growth. The overall area of aspen-birch in the North declined from 24.6 million acres in 1953 to 16.8 million acres in 1997 (Smith et al. 2001). In addition, as part of the array of forces at work, NIPF owners are increasingly motivated by objectives other than timber production and harvest. Population growth has contributed to an increasing number of second homes, especially around lakes and other water areas, which has affected the availability of some aspen-birch timberland for timber harvests.

The total area of aspen-birch in the Lake States decreased by 7.8 million acres between 1953 and 1997.

In the Northeast, the largest changes in the areas of forest covers on private timberlands are projected for NIPF timberlands (fig. 10); however, forest industry's lands (fig. 9) have larger projected changes relative to the total amount of timberland in the respective ownership categories. On NIPF timberlands, the largest forest cover changes are projected losses of maple-beech-birch and spruce-fir forest covers and projected increases in the areas of the aspen-birch and oak-pine forest covers. Maple-beech-birch is projected to lose almost 1.7 million acres of land by 2050 (11 percent of the initial forest cover area), whereas spruce-fir is projected to decrease by almost 1.3 million acres (34 percent) within the same period. Aspen-birch and oak-pine are projected to increase by 0.7 (34 percent) and 0.4 (24 percent) million acres, respectively.

On the forest industry lands in the Northeast, the largest relative change is a 70-percent increase in the area of white-red-jack pine, an increase of approximately 0.2 million acres by 2050. All other forest industry forest covers are projected to decrease, especially the oak-hickory and maple-beech-birch forest covers with losses of 0.6 (15 percent) and 0.3 (6 percent) million acres, respectively.

Summary, North Region

Soils are generally well suited for forests, which are the natural potential vegetation for most of the region. Northern forests tend to have relatively diverse mixtures of tree species. The region has been heavily disturbed by human activities. Most of the forest is privately owned, and the diversity of landowner objectives can promote species and seral diversity. Hardwood forest types dominate the region's forest land. The oak-hickory and maple-beech-birch forest cover types are the largest in the North, combining to represent 62 percent or 106 million acres of unreserved forest land. Between 1953 and 1997, the area of maple-beech-birch more than doubled, adding 27 million acres. The largest projected changes in forest cover areas are decreases for the spruce-fir and aspen-birch types and increases in the areas of lowland hardwoods (including red maple-dominated forest types) and maple-beech-birch. Projected area changes for hardwood forest cover types are largely based on a continuation of recent trends, whereas softwood cover types are projected to diverge somewhat from historical trends. Timber harvest is important regarding projected changes in forest cover type areas, and levels of timber harvest will allow the aggregate NIPF hardwood inventory to continue to rise; industrial timber harvest will be equal to or slightly less than timber growth, and inventory will rise slightly over the projection.

Chapter 2: South

Introduction

The South includes 13 states of the Southeastern and South Central subregions (fig. 1, table 1). The area extends from Virginia southward and westward along the Atlantic and Gulf seaboards to Texas and includes the interior states of Arkansas, Kentucky, Oklahoma, and Tennessee. This region is characterized by a variety of climatic and edaphic conditions that relate to its diverse physiography (USDA Forest Service 1989). The South covers portions of five physiographic divisions: the Atlantic Plain, the Appalachian Highlands, the Interior Highlands and Piedmont, Delta, and the Interior Plains. Elevations range from the coastal flats to mountains of the Blue Ridge province that have peaks over 6,000 feet. The climate ranges from subtropical with rainfall averaging 40 to 60 inches annually in parts of the coastal plains to more arid conditions in parts of the Interior Plains.

Forest land totals 214 million acres or 40 percent of the South's land area.

The South is heavily forested from Virginia to the forest's limit in eastern Texas and Oklahoma. Forest land totals 214 million acres or 40 percent of the region's land area, with five states being more than 60 percent forested. The Southeast is 60 percent forested, whereas the South Central subregion is only 32 percent forested owing in large part to the large areas of range and scrubland in Texas and Oklahoma. The fraction of forest land that is classified as timberland has remained fairly constant at about 96 percent over the past half century, reflecting the inherent productivity of the forest-land base and the general availability of forest land for timber operations (fig. 4).

The South has some of the most commercially important timber species, such as loblolly pine (*Pinus taeda* L.), and forestry and forest products are important industries in the region. Human disturbances are a dominant force affecting forest structure and composition (Alig and Wyant 1985, Wyant et al. 1991). The largest human disturbance is timber management, which includes commercial timber harvests along with precommercial thinnings, mechanical and chemical site preparations, planting of seedlings, prescribed burning, fertilization, fire protection, and herbicide and pesticide applications (Dubois et al. 1999). In recent years, the South has harvested more timber than any other country (Wear and Greis 2002). The region also is looked to as a source of more timber in the future, including an increasing share from relatively fast-growing pine plantations (Alig et al. 2002b, Haynes 2003).

Private timberlands compose around 90 percent of the U.S. South timberland (Smith et al. 2001). The behavior of the groups and individuals who own these lands has led to a substantial expansion of pine plantation area in the U.S. South (Kline et al. 2002). Within its relatively large timberland base, the South contains two-thirds of the Nation's tree plantations. The South is the leading tree planting area in the

United States for a number of reasons, including a favorable climate (long growing season and generally abundant precipitation), historically good timber markets and the heavy concentration of forest industry in the region, and comparatively less competition for land from some major agricultural field crops (e.g., corn). The economic attractiveness of tree planting in the South was enhanced by reduced timber harvests on federal lands concentrated in the West. Agriculture is an important and diversified sector of the regional economy, but it is based largely on fruits and vegetables, rice, tobacco, cotton, poultry, hogs, and cattle, and is not a significant producer of major field crops such as corn and wheat.

Upland hardwood is the dominant forest type on nonindustrial private timberlands in the South and planted pine is the dominant forest type on forest industry lands.

Forest Cover Situation

The region's timberland area is still dominated by hardwood forest types (Smith et al. 2001) (fig. 13, table 2). More than one-half of the region's timberland has hardwood cover. Based on the broad forest cover types surveyed by the USDA Forest Service Forest Inventory and Analysis (FIA) unit, the upland hardwood type covers the most area (e.g., oak-hickory), followed by planted pine, natural pine, lowland hardwoods (e.g., elm-ash-cottonwood), and oak-pine forest types.

Upland hardwood is the dominant forest type on nonindustrial private forest (NIPF) timberlands, whereas planted pine is the dominant forest type on forest industry timberlands. In 1997, upland hardwood accounted for 68 million acres of timberland or 38 percent of total southern private timberland (fig. 14), with over 80 percent of this area on NIPF timberlands.

Fourteen percent of southern private timberland is currently covered by pine plantations.

Although the area of pine plantations has increased substantially in the Southern United States, only about 14 percent of the total southern private timberland is currently covered by pine plantations (figs. 15 and 16). Across the South, a proportionately larger amount of forest industry timberland (39 percent) is planted compared to NIPF timberland planted (10 percent). Planted pine is the dominant forest type on forest industry timberlands. Forest industry owned over half of the 30 million acres of planted pine located in the U.S. South in 1997, although NIPF owners possess about four times as much timberland in total. Many of the plantations are found in the Coastal Plain, the geographic area that stretches inland along the coast from Virginia to Texas, with gentle slopes and little local relief.

In addition to the 30 million acres of planted pine, the South has about 6 million acres of plantations in other forest types (e.g., oak-pine). Many of these represent original pine plantations that later reverted to other types owing to natural seeding in and resprouting of hardwoods. Approximately equal amounts of such planted nonpine types occur on forest industry and NIPF timberlands.

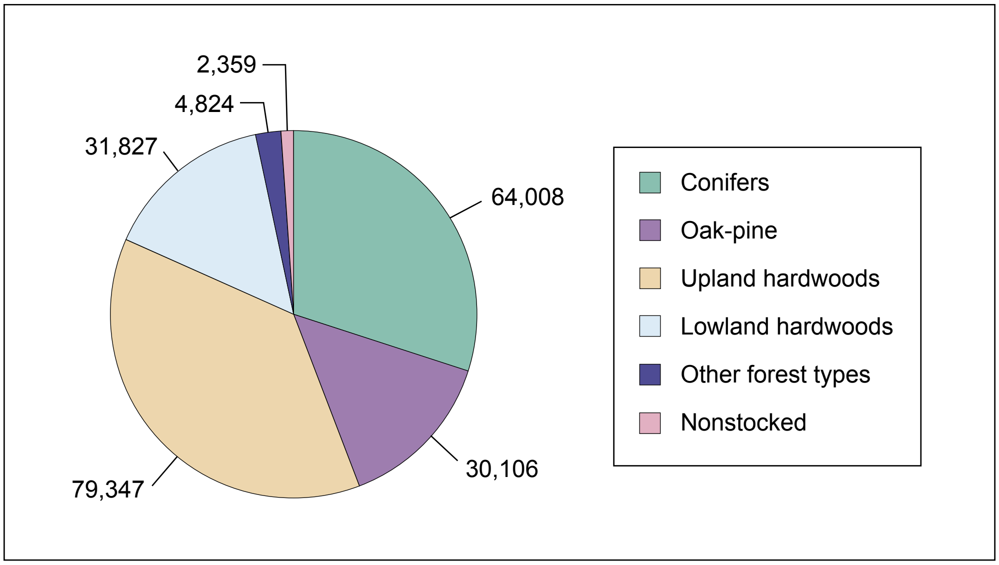


Figure 13—Area of forest land (thousand acres) by forest cover type in the South region, 1997 (Smith et al. 2001).

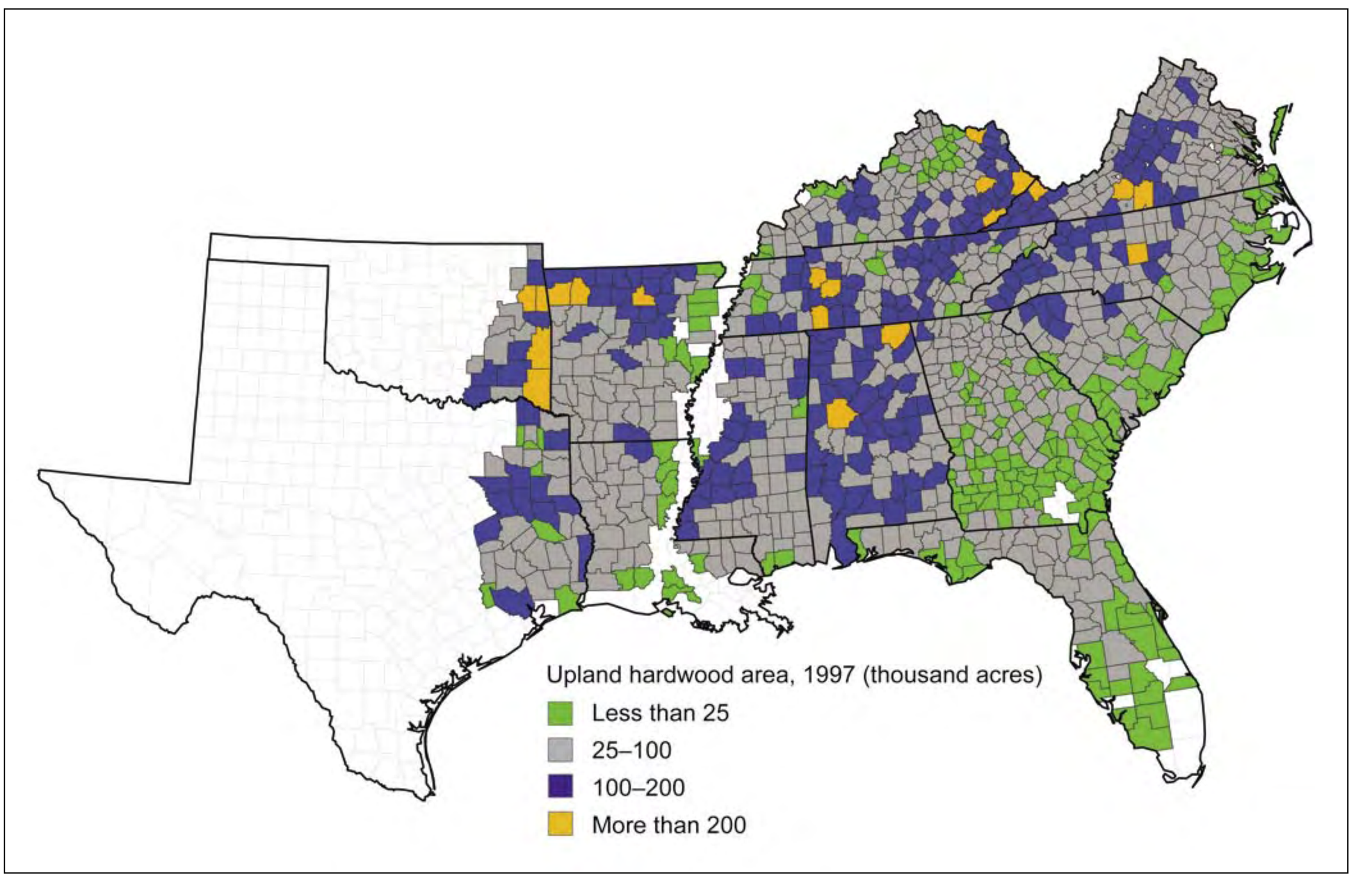


Figure 14—The 1997 distribution of upland hardwood forest type on private timberland in the South region. White portions of the map have no significant upland hardwood area.

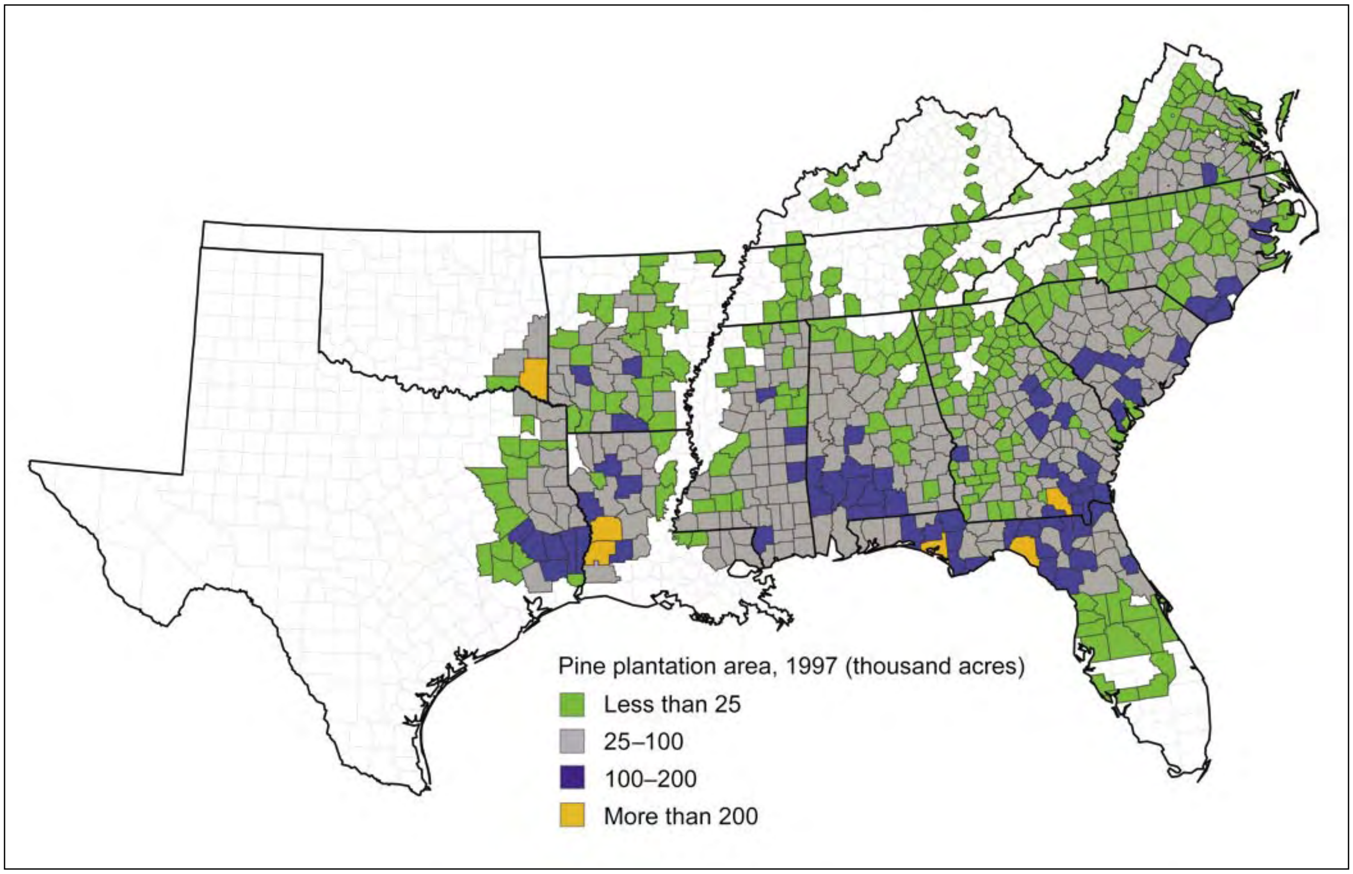


Figure 15—Map of the 1997 distribution of pine plantations on private timberland in the South region. White portions of the map have no significant pine plantation area.

Figure 16—Area of pine plantations in the South region increased more than tenfold from 1953 to 1997.

The silvicultural system and the amount of capital invested in stand establishment are major factors influencing forest type dynamics in the South. These factors are particularly important for pine dynamics because "pines need help to regenerate" (Knight 1973), and regeneration establishment success can differ markedly by ownership (McWilliams and Moulton 1991). Knight (1978) reported that in many areas, hardwoods replaced pines on about half of the area harvested. Between 1975 and 1985, clearcut silvicultural systems were used to harvest two-thirds of forest industry's pine stands and about one-third of NIPF pine stands; the remainder of the harvested stands was harvested with partial harvest silvicultural systems. The specific prescriptions also differed between ownerships. For example, 63 percent of the clearcuts on NIPF private lands left significant amounts of low-value trees, often hardwoods, which would significantly hinder the ability of a stand to commercially regenerate (McWilliams and Moulton 1991). This has led to historically low rates of pine stands regenerating as pine stands following human disturbances, although the percentage of harvested stands regenerating as pine has been increasing (Alig 1985, Birdsey et al. 1981, Boyce et al. 1975, McWilliams and Moulton 1991) and the potential for further improvement appears to be substantial.

The largest historical changes in forest cover types have been a decrease in the area of naturally regenerated pine and increases in the areas of planted pine and upland hardwood.

Between 1953 and 1997, the South had some relatively large area changes for forest types (fig. 17). The largest changes in forest type areas have been the decrease of naturally regenerated pine, the increase of planted pine, and the increase of upland hardwood. Naturally regenerated pine lost a total of 59 percent of its area between 1952 and 1997, whereas planted pine increased eighteenfold. All ownerships had marked gains in planted pine, whereas most of the loss of natural pine has been on NIPF timberlands. The area of upland hardwood has been steadily increasing, especially on other private timberlands. The area of lowland hardwood has been steadily decreasing, especially on NIPF timberlands. The area of oak-pine has remained relatively constant at the regional level, but the Southeast has had a net gain and the South Central has had a net loss of oak-pine.

Another major factor affecting trends in planted pine areas has been the afforestation on NIPF lands that have been subsidized by the Conservation Reserve Program (CRP) or other planting programs (Moulton and Hernandez 1999). Georgia led the Nation in the amount of CRP tree planting, but the increases in timberland owing to that program, the spinoff of industry lands, and other factors did not offset losses of timberland in the Southeast owing to conversions to urban/developed uses and other uses. The situation in the South Central differed, in that net gains to timberland area were about four times as large as the loss in forest industry timberland area. These gains were due to CRP tree planting on formerly agricultural land, reversion of other lands to forest, and lands being reclassified out of the industry

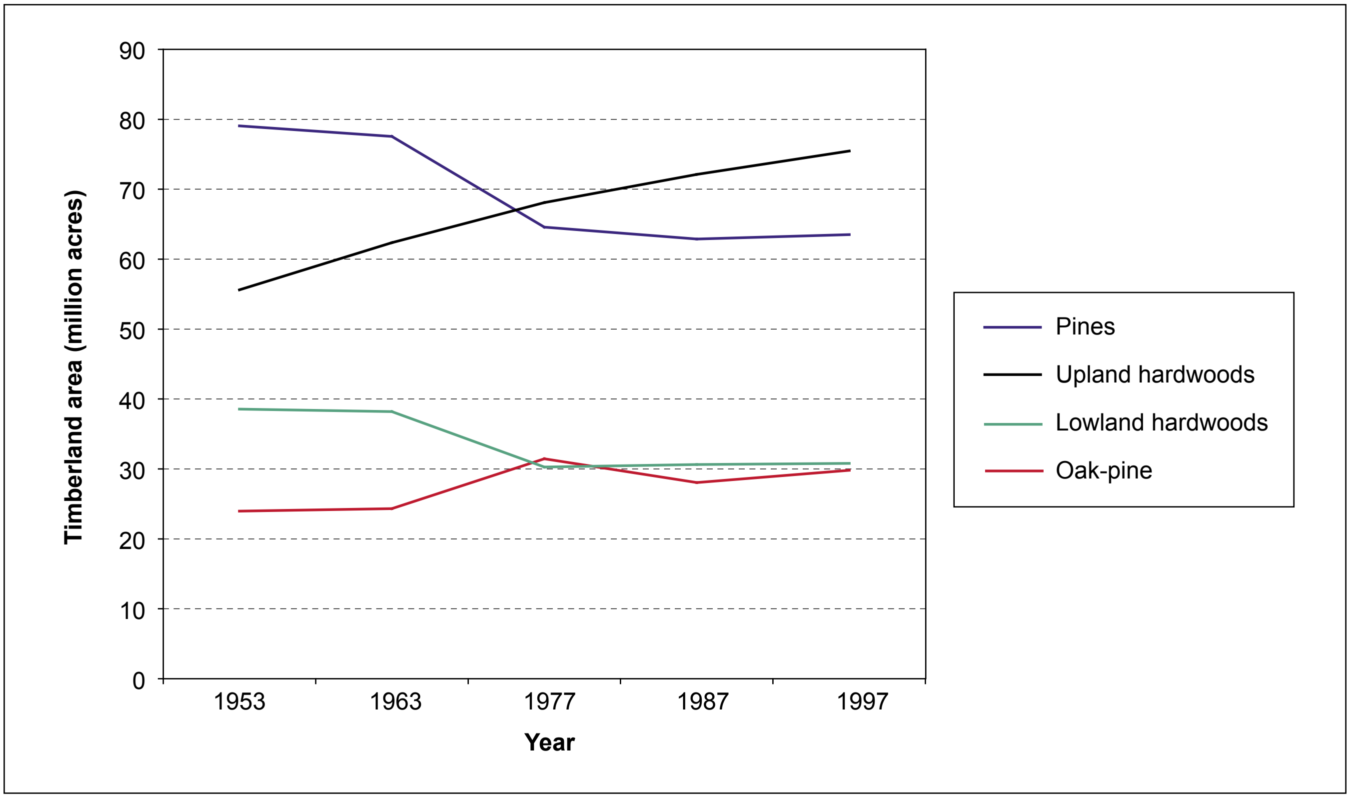


Figure 17—Area trends for major forest cover types on timberland in the South region, 1953 to 1997 (Smith et al. 2001).

ownership class. The trend in increased timberland area in the South Central, along with the larger starting size of the subregion's timberland base, are consistent with the larger projected increments in planted pine area in that subregion compared to the Southeast.

Changes in timber harvesting in the South include an increased number of chip mills. Wood chipping has always been an integral part of the process of using wood to make paper; however, there is a growing trend of using wood chips in other types of products used in building construction. Chip mills grind whole trees into chips for pulp, paper, and particleboard. Satellite chip mills or other wood processing facilities are efficient in terms of transportation, productivity, and wood utilization. Lower grade and younger trees can be thinned from forest land to provide chips, both for silvicultural practices (such as thinnings) as well as meeting other objectives such as wildlife habitat and aesthetics.

Planted pine area in the South increased by more than 25 million acres between 1952 and 1997.

Projections

Changes in total timberland area affect the amount of land available for each forest cover type. Deforestation because of growth in human population and subsequent expansion of urban and developed uses is the reason that Southern timberland area is projected to decline from about 201 million acres in 1997 to 198 million acres in 2050, owing to losses of private timberland (Alig et al. 2003). Most of the projected net reduction is in the Southeast region, especially around large urban areas such as Atlanta. In some states, particularly in the east Gulf area of Florida and Georgia, where substantial increases in population and economic activity are expected, the drop is also fairly large. In most of the other Southern states, the projected changes are small, and in the South Central subregion, the aggregate area of timberland is projected to increase slightly (e.g., Ahn et al. 2001).

Pine plantations in the South are projected to increase by 14 million acres by 2050.

Overall, the percentage of the timberland area in softwood types is projected to increase relative to that in hardwood types (table 3). However, the total area in hardwood types is projected to dominate that in softwood types.

Planted Pine

Planted pine area on private lands [1] increased by more than 25 million acres between 1952 and 1997, more than a tenfold increase. The private area in pine plantations is projected to increase by about 14 million acres by 2050, approximately a 52-percent increase (fig. 18). More than half of the additional planted pine acres are projected for forest industry lands (figs. 19 through 22). With management intensification on these industrial lands, many harvested natural pine, mixed-oak-pine, and hardwood stands are being artificially regenerated. The planted pine forest type accounts for nearly 60 percent of forest industry softwood area at the start of the projection, and increases to 75 percent (an addition of 7.6 million acres) by 2050.

Most of the planted pine is projected to be gained in the South Central subregion.

The area of planted pine is increasing across all ownerships in both regions and will continue to be concentrated in the Coastal Plain (fig. 23) (Alig 1985). Overall, most of the planted pine is projected to be gained in the South Central subregion (figs. 21 and 22). The South Central subregion has the majority of cropland and pastureland that could yield higher rates of return if planted to pine (USDA Forest Service 1988).

Larger areas of planted pine are projected for forest industry than for NIPF owners in both the Southeast and the South Central subregion (figs. 19 through 22). This increase is largely a product of intensification of forest management practices and the increasing demand of the wood fiber processing industries in the South. With management intensification on industrial lands (e.g., Alig and Wear 1992, Alig et al. 1999, USDA Forest Service 1988), many harvested natural pine, mixed-oak-pine, and hardwood stands are being artificially regenerated to pine plantations.

[1] Additional FIA data allow the nonindustrial private forest ownership class to be separated into miscellaneous corporate and other private classes (see "Glossary") in the South.

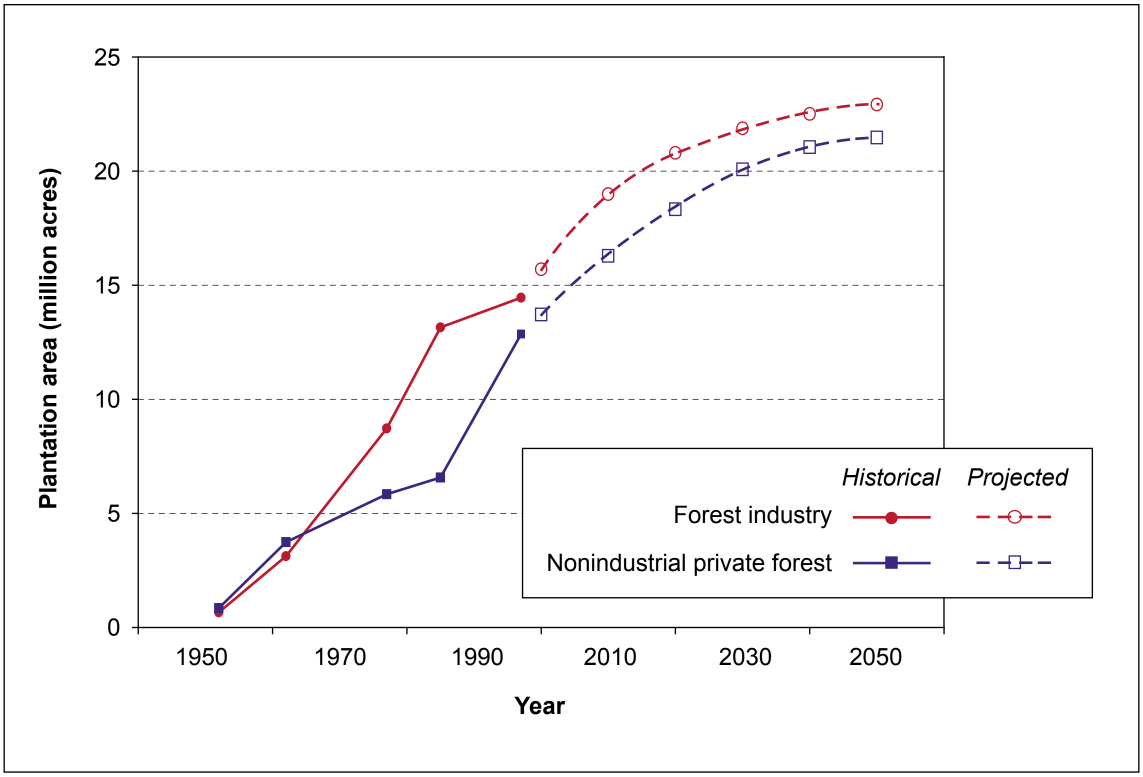


Figure 18—Area of the planted pine type on private timberland in the South region, 1952 to 1997, with projections to 2050.

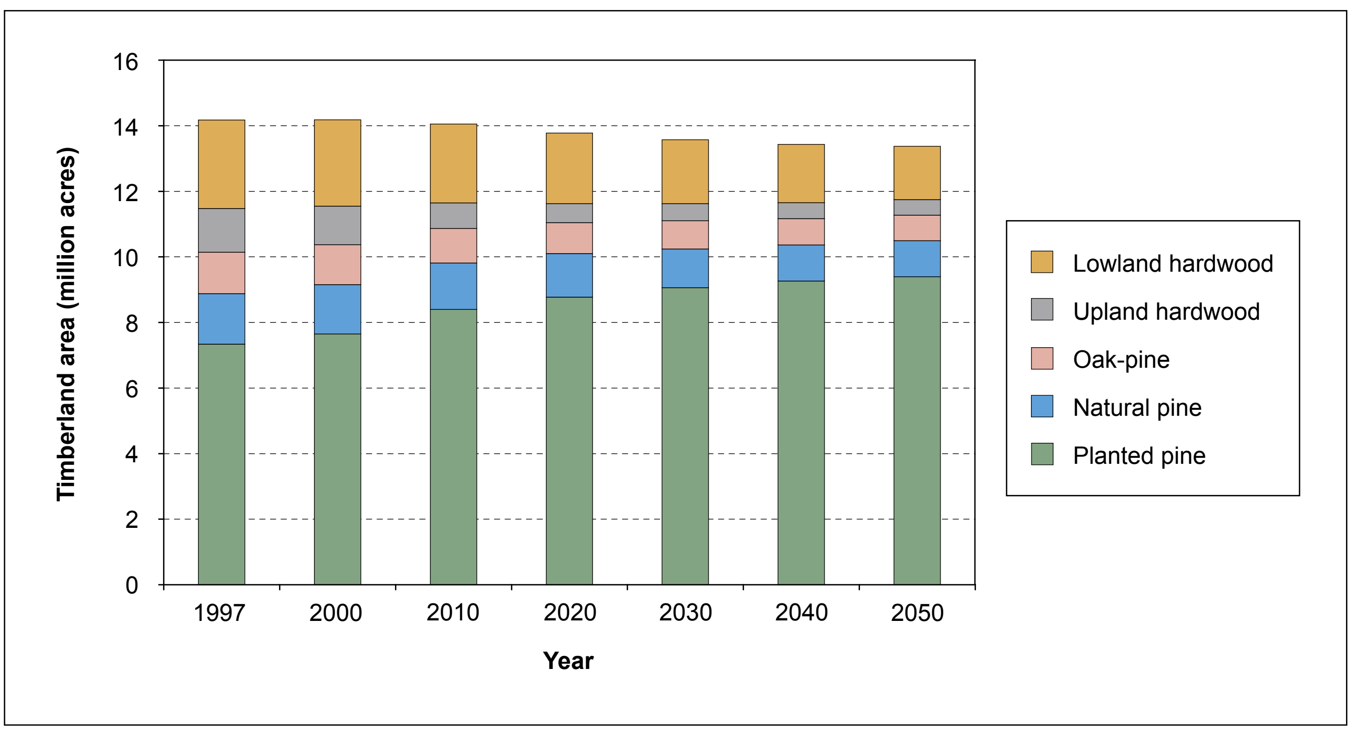


Figure 19—Projected area changes for forest cover types on forest industry timberlands in the Southeast subregion, 1997 to 2050.

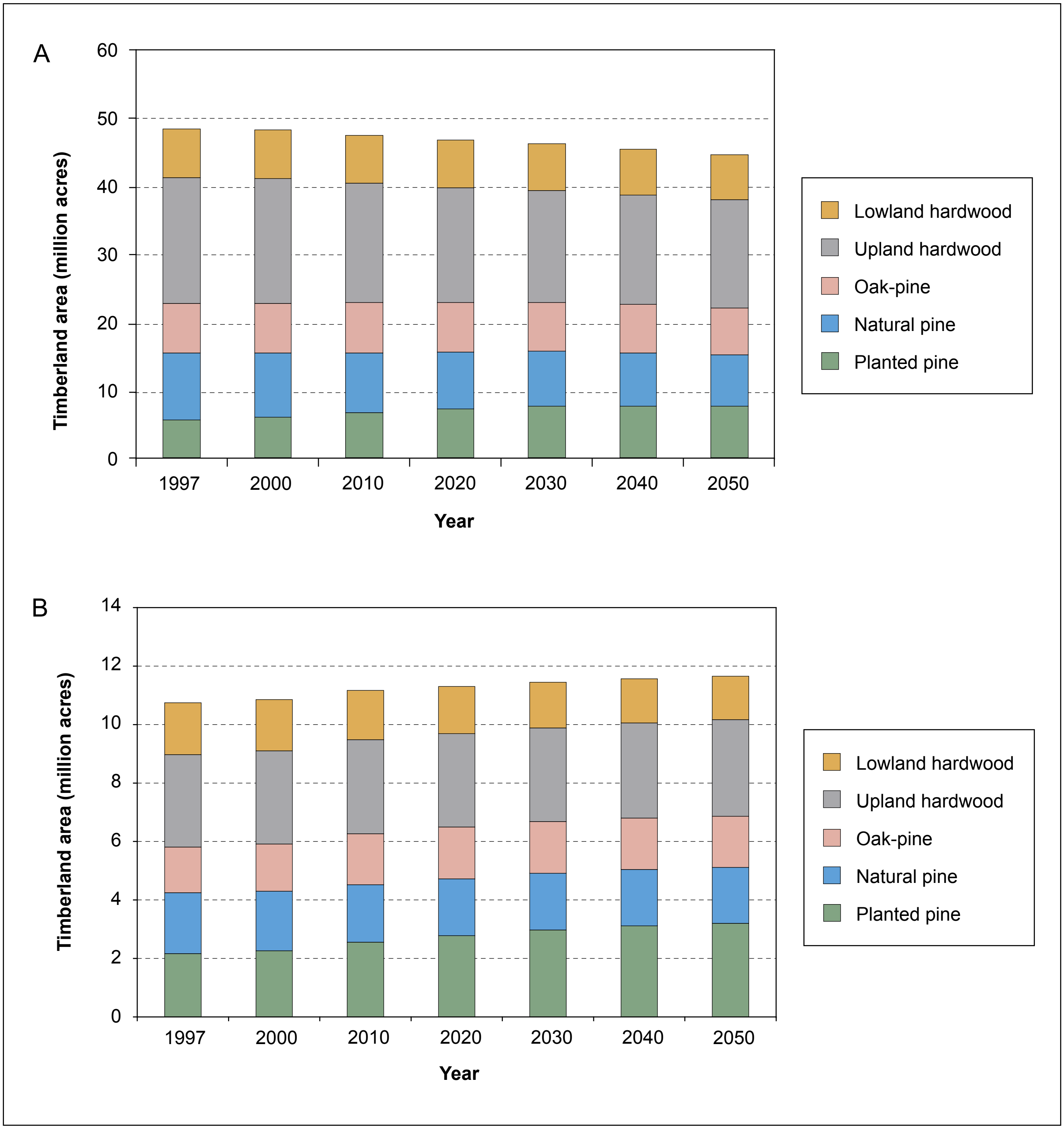


Figure 20—Projected area changes for forest cover types on nonindustrial private timberland in the Southeast subregion, 1997 to 2050: (A) other private timberlands and (B) miscellaneous corporate timberlands.

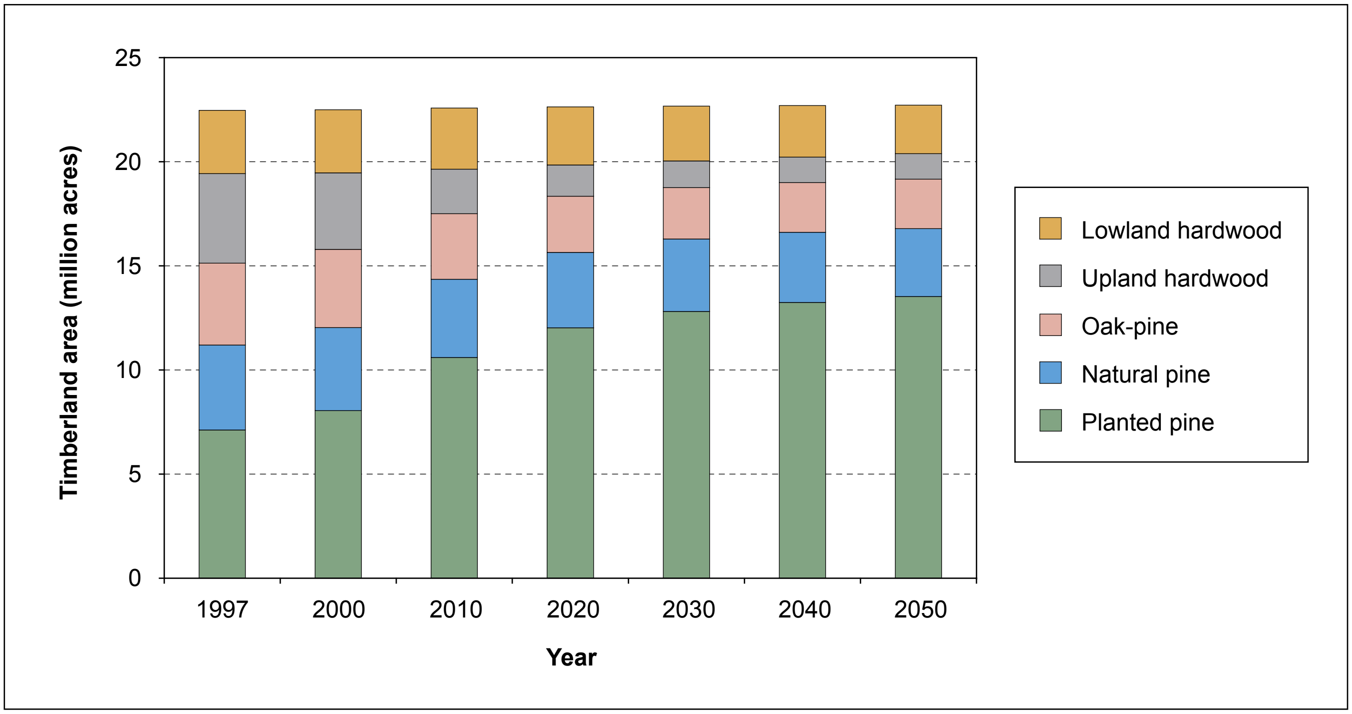


Figure 21—Projected area changes for forest cover types on forest industry timberlands in the South Central subregion, 1997 to 2050.

Nonindustrial private forest owners in the South are projected to add 5.6 million acres of planted pine by 2050.

For the forest industry ownership, regeneration moves most future stands into more intensive management categories (Haynes 2003). This trend is in line with the traditional industrial forestry objective to more efficiently and economically produce timber crops. We assume that this objective will be maintained on forest industry lands despite projected periods of flat to declining pulpwood stumpage prices for several decades. Indeed, the projected market outcome reflects, in large part, the achievement of industrial forestry objectives (abundant supplies of fiber resources for decades to come), but it also reflects impacts of projected trends on the demand side, including decelerating paper and paperboard demands, rising product imports, and a period of relatively stagnant pulp mill capacity growth over the next decade.

The shift in planted pine is not quite so dramatic for NIPF owners. Although the NIPF ownership begins the projection period with nearly as many acres of planted pine as industry, natural pine and oak-pine make up over three-quarters of NIPF softwood timberland. The NIPF owners are projected to add 5.6 million acres of planted pine by 2050, with two-thirds of the NIPF acres in the other softwood types.

Kline et al. (2002) showed that the reasons for planting trees differed by ownership. On forest industry lands, tree planting was primarily a function of harvest levels, land value, and interest rates. On other private lands, harvest levels, planting

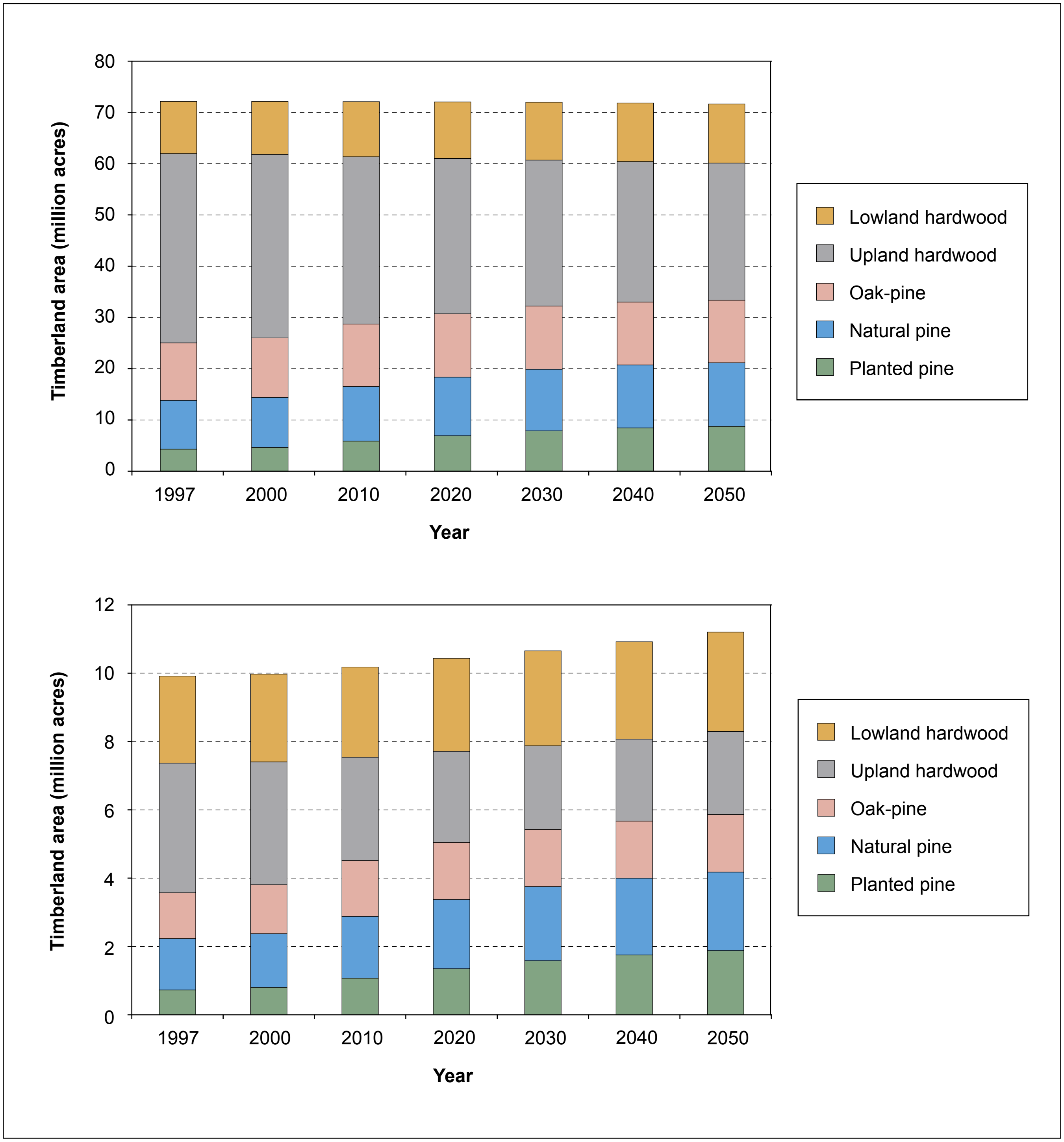


Figure 22—Projected area changes for forest cover types on nonindustrial private timberland in the South Central subregion, 1997 to 2050: (A) other private timberlands and (B) miscellaneous corporate timberlands.

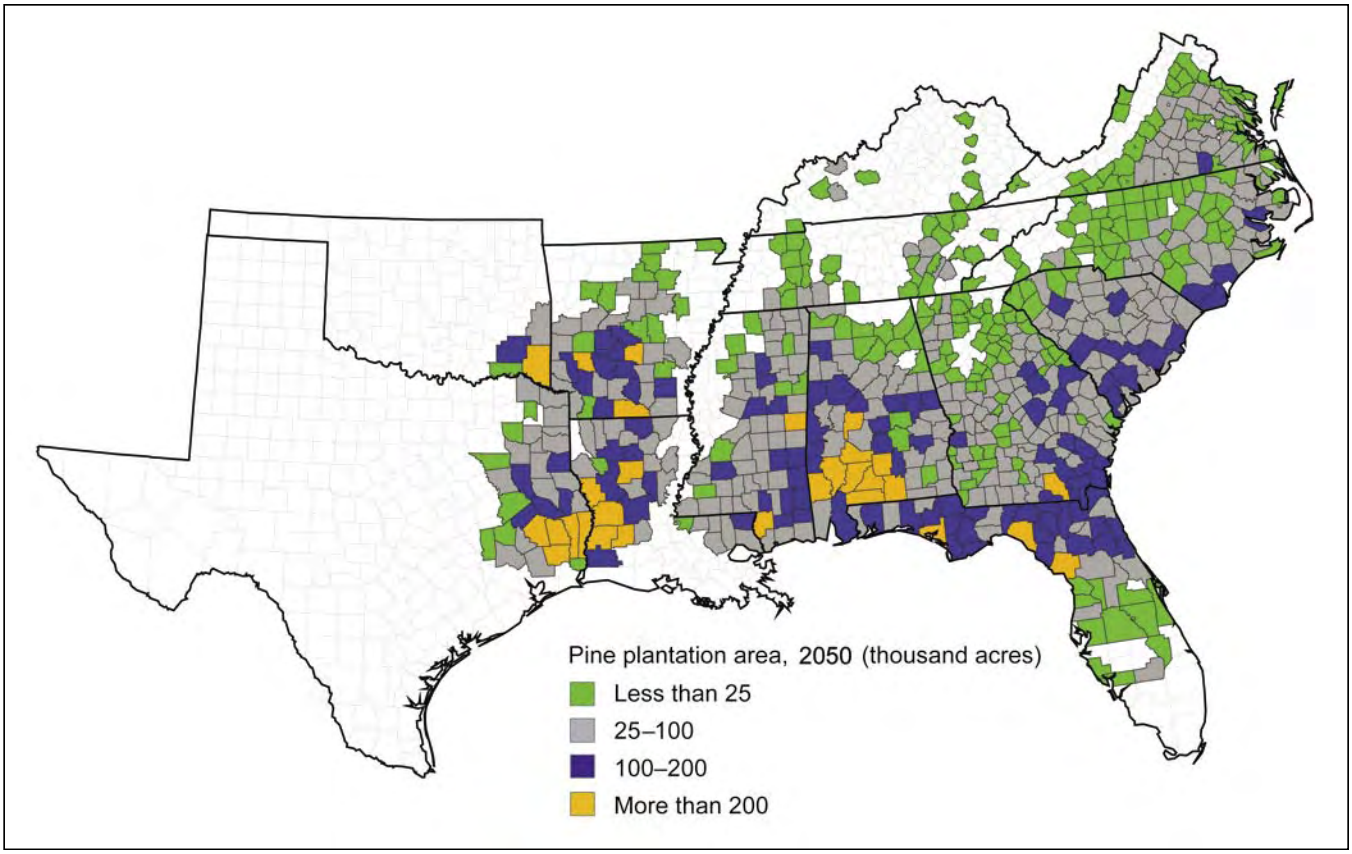


Figure 23—Projected distribution of pine plantations on private timberland in the South region, 2050. White portions of the map have no significant pine plantation area.

The projected loss of natural pine in the South is largely due to land use conversions and transitions to planted pine and upland hardwood following final harvests.

costs, land values, and government planting programs were significant factors. The tree planting programs of the U.S. Department of Agriculture have resulted in the afforestation of millions of acres in the South by providing incentives for farmers to convert agricultural lands to pine plantations (Moulton 1999, Moulton and Hernandez 1999). Public policies will probably continue to have a major impact on forest dynamics in the South, but the specifics of these policies are a large uncertainty in the region's future. Our projections assume a continuation of recent planting assistance policies, such that the funding for tree planting programs is assumed to remain constant in real dollar terms at levels in place after the historically high tree planting levels under the CRR (fig. 18).

Differences in forest cover type trends among ownership groups result in part from different forest management objectives and constraints. Although the forest industry has timber production as its primary objective, NIPF owners may own their land for timber production, land speculation, recreational activities, or numerous other objectives. The fact that the forest industry has more or nearly equal areas of planted pine, even though they have a much smaller land base, is an attribute of their stronger timber management objectives and the capital resources that they have available for establishing and maintaining pine plantations. Expansion of NIPF pine plantation area is promoted not only by market incentives but also by various state and federal forestry incentives, and by many local cooperative arrangements with industry.

The area of planted pine is now nearly equal to the area of natural pine and it is projected to significantly exceed the area of natural pine in the future. The projected loss of natural pine is largely due to land use conversions and transitions to planted pine and to upland hardwood following final harvests. These transitions and conversions are driven by profit maximization objectives and biological factors. In addition to direct human actions, natural succession and the suppression of natural disturbances (e.g., fire) contribute to the reduction of natural pine by reducing the competitiveness of the pines and thus promoting transitions of natural pine to upland hardwoods (e.g., Knight 1973, USDA Forest Service 1988).

Area of natural pine on private lands is projected to decrease by 15 percent over the projection period in the South, with most of the loss being on nonindustrial private forest lands in the Southeast subregion.

The projections of forest type changes in the South for the 2000 Renewable Resources Planning Act (RPA) assessment are largely consistent with those in the South's Fourth Forest study (USDA Forest Service 1988) and related studies (Alig and Wear 1992, Haynes et al. 1995). Using a common projection year of 2030, but projections of planted pine area in the 2000 RPA assessment are approximately 4 percent lower than those in the study of the South's Fourth Forest. The percentage difference is relatively small compared to the overall projected increase in private planted area of about 130 percent between now and 2030.

Naturally Regenerated Cover Types

Shifts in management among the natural pine, oak-pine, upland hardwood, and lowland hardwood forest types, which are all considered to be naturally regenerated, can be seen in figures 19 through 22. All four cover types are projected to have a net loss of area. Transitions between planted and naturally regenerated stands involve significant amounts of two-way flows, including substantial numbers of harvested pine plantations reverting to naturally regenerated forest types.

Area of natural pine on private lands is projected to decrease by 15 percent over the projection period. Many exchanges occur between forest cover types owing to natural succession and management (e.g., regeneration method after harvest). Losses include an assumed continuation of trends in substantial hardwood encroachment after harvest of pine stands on NIPF lands, a topic that has been raised as an issue for several decades (e.g., Alig 1985; Knight 1973, 1985). Gains include reversions to timberland from abandoned agriculture land that seed in as pine in some cases, and some transitions from oak-pine to natural pine dominance in a stand.

The upland hardwood forest type in the South is projected to lose 12 million acres by 2050.

The greatest loss of natural pine is projected for the Southeast subregion, particularly on NIPF lands (fig. 20). Some NIPF pine acres are projected to be converted to developed uses. This is particularly the case for the Piedmont region that has substantial population centers and interstate highways. The Piedmont is a plateau between the mountains and Coastal Plain, where many natural pine stands were established following periodic abandonment of cropland. Natural hardwoods are encroaching in many unmanaged pine stands.

Natural pine areas are projected to decrease on forest industry lands in both subregions, but these losses are offset by increases on NIPF timberlands in the South Central subregion (fig. 22). Forest industry has a much smaller relative share of total timberland area in the South than NIPF owners, and this is especially true for ownership of naturally regenerated acres. Overall, forest cover types other than planted pine on industrial lands are projected to lose 38 percent of their area (8.6 million acres) by 2050. Most of this change is not a loss of timberland, but a shift, or conversion, to planted pine. The greatest shift projected is a 59-percent reduction in area of upland hardwoods on forest industry timberlands (3.4 million acres). The natural pine type would be reduced by 35 percent (2 million acres). Significant shifting is projected within natural pine, however, as the area doubles in the partial cutting regime projected in the RPA timber assessment (Haynes 2003). Shifting to more intensive levels of even-age management does occur, but the movement out of these types masks the change.

The largest shifts in management of the naturally regenerated forest types are projected for NIPF timberland. On the NIPF ownership, more than 7 million acres of natural pine and upland hardwoods are projected to be converted to other types or nonforest uses. This represents less than 6 percent of the area in cover types other than planted pine. The shift to managed stands outweighs the loss of area for timber production, as area assumed to be managed under the high timber management regime more than doubles in the RPA timber assessment projections (Haynes 2003).

The largest area decrease projected is for the upland hardwood type, with a 12-million acre or 18-percent loss projected by 2050. The projection represents a change from long-term historical trends for the South. A combination of factors underlies the projected reduction: conversion to nontimberland land uses, conversion to pine plantations, and transitions to other types including oak-pine. Historically, a large source of upland hardwood was reversion of agricultural fields to forest, especially in the South Central subregion. Although some of this reversion is still occurring, larger amounts of land are being converted from upland hardwood to urban and agricultural uses and to planted pine. The projected rate of reduction in upland hardwood area slows as market incentives for conversion to pine plantations lessen with stable to falling softwood prices. Hardwoods will continue to dominate the forested landscape of the South. Hardwood forests in 2050 are projected to cover about one-half of the southern private timberland base, twice the amount for planted pine in the region (figs. 24 and 25).

The transition matrices for the no-harvest case show relatively low annual probabilities that any given forest type would transition to a different forest type. On average, it takes over 100 years for a forest to transition to another forest type in the absence of a harvest. These transitions result from natural succession, natural disturbances, and human disturbances other than final or partial harvests, such as control of competing vegetation. Oak-pine had the highest annual probability (6 percent) of transitioning to another forest type. In projections for forest industry lands, planted pine was the most common forest type to which oak-pine transitioned, whereas oak-pine on miscellaneous corporate and other private timberlands (see footnote 1 on page 25) transitioned to natural pine and upland hardwood. These transitions are a result of oak-pine being a relatively "unstable" forest type, and slight changes in stand stocking can result in reclassification of the forest type.

The probability of a forest type transition following a partial harvest differed by forest type and subregion. Lowland hardwood had the highest and oak-pine had the lowest probabilities of remaining the same forest types following a partial harvest. The oak-pine forest type tended to transition to the upland hardwood forest type, whereas the other forest types tended to transition to oak-pine. The probabilities of forest type transitions following partial harvests were higher in the South Central subregion than in the Southeast.

The final-harvest forest type transition probabilities differed significantly by forest type, ownership, and subregion. The lowest probabilities for a forest type remaining in the same forest type after a final harvest were for natural pine, an average of 9 percent. The highest probabilities of forest types remaining in the same forest type following final harvests were for lowland hardwood and planted pine. Planted pine and upland hardwood were the most common fates for transitions of forest types after final harvest. An example of the regional and ownership differences is the probability that planted pine will remain in planted pine following a final harvest. The probability is much higher in the Southeast and for forest industry owners. The forest type transition matrices from AF&PA (1999) and Moffat et al. (1998) showed trends similar to the FIA-based matrices (also see app. 1), with the exception that the AF&PA and Moffat et al. matrices showed higher retention of planted pine and higher transition rates to planted pine.

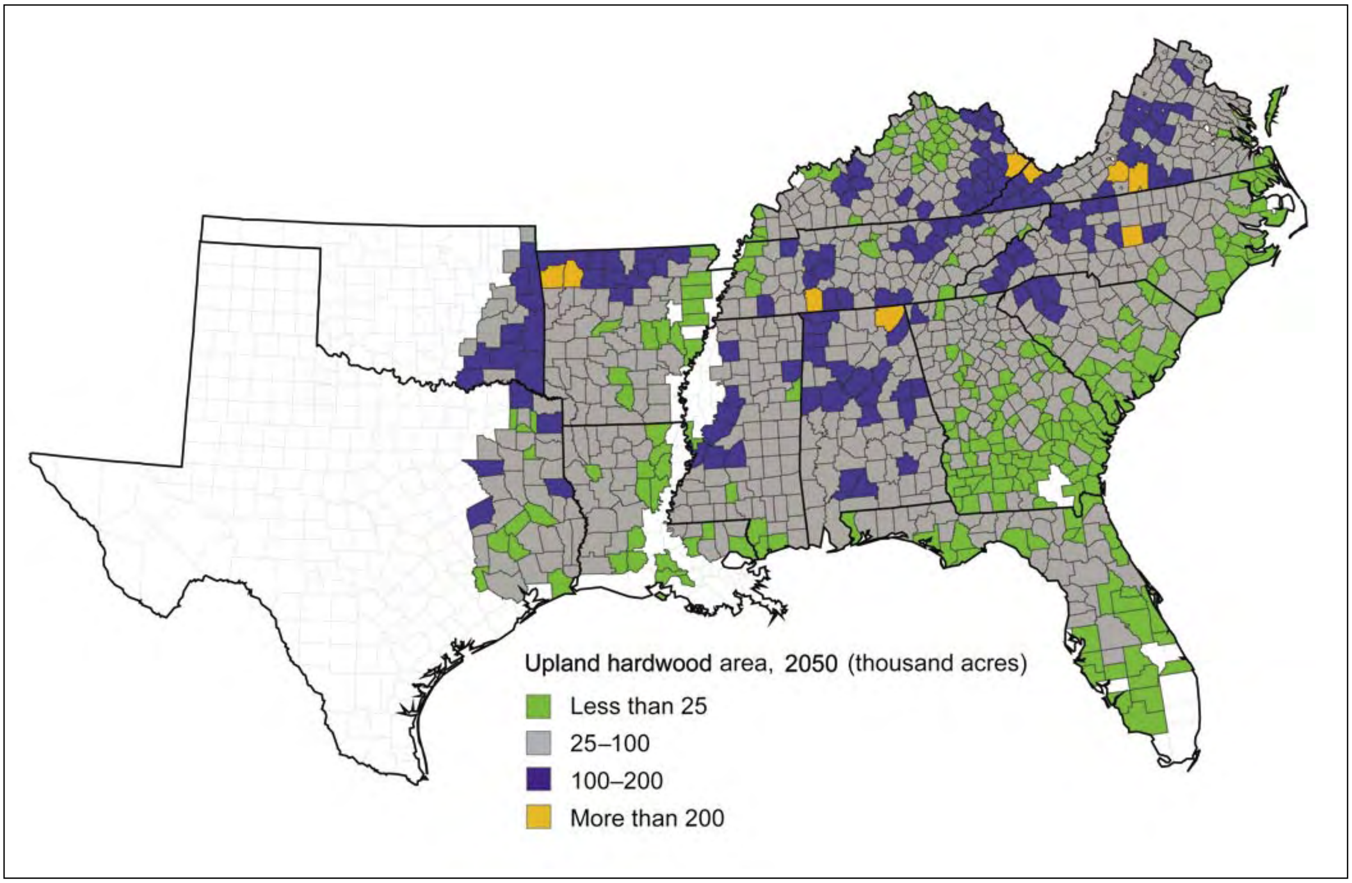


Figure 24—Projected distribution of the upland hardwood forest type on private timberland in the South region, 2050. White portions of the map have no significant upland hardwood area.

Final harvest transition probabilities differed significantly by forest type, ownership, and subregion.

Figure 25—Hardwood forest cover types cover the most timberland in the South region.

The projection of an increasing area of lowland hardwood on NIPF private timberlands in the South Central may be an indication that federal and state policies are having their desired effects. The Swampbuster provision of the 1985 Farm Bill, coupled with changes in the federal tax code (Moulton and Dicks 1990) to discourage the conversion of wetlands to agricultural uses, the Wetland Reserve Program, the federal no-net-loss of wetlands policy, and other actions by federal and state governments and by conservation organizations working with landowners may be having the intended effect of protecting and restoring valuable forested wetlands. This projected increase is partially attributable to the transition of upland to lowland forest types. As this may occur at small scales and may not be a long-term pattern, this transition probability was set to zero, and the area of lowland hardwoods followed the historical trends.

One of the largest changes in U.S. forest type areas has been the increase in planted pine.

The area of natural pine was projected to decrease by both the South's Fourth Forest study (USDA Forest Service 1988) and the 2000 RPA assessment. Natural pine area is affected by transitions among all five major forest cover types in the South (Alig et al. 1986). The relatively large amount of transitions among forest types, especially after final harvests, is consistent with earlier studies (e.g., Alig 1985, Knight 1973, USDA Forest Service 1988) and timber policy analyses suggesting many opportunities to accelerate regeneration of harvested stands and increase forest stocking. Regeneration lags and a somewhat stochastic mixture of regenerated species may be beneficial for some wildlife species using the forests, but those topics and related tradeoffs are outside the scope of this particular study. The empirically based type transition modeling does suggest that the Southern forest is quite dynamic and varied in composition, in contrast to speculations about monocultures covering a large part of the region.

Summary, South Region

In 1997, the area of private timberlands in the Southern United States was dominated by upland hardwoods, followed by planted pine, natural pine, lowland hardwoods, and oak-pine forest types. One of the largest changes in U.S. forest type areas over the last half century has involved pine types in the South. Area of planted pine has increased more than tenfold since 1950, mostly on private lands. Planted pine area on private lands increased by more than 25 million acres between 1952 and 1997. Management intensification on these industrial lands is one of the reasons some harvested natural pine, mixed oak-pine, and hardwood stands are being artificially regenerated to pine plantations. Private landowners have responded to market incentives and government programs, including subsidized afforestation on marginal agricultural land. Timber harvest is a crucial disturbance affecting planted pine area, as other forest types are converted to planted pine after harvest. The private area in pine plantations is projected to increase by about 17 million acres by 2050, approximately a 53-percent increase largely owing to the addition of pine plantations on forest industry lands. Conversely, many harvested pine plantations revert to other forest types, mainly owing to passive regeneration behavior on nonindustrial private timberlands.

The area of natural pine on private lands is projected to remain constant. Although there are many exchanges among forest cover types owing to natural succession and management (e.g., regeneration method after harvest), the gains and losses essentially offset each other. Losses include an assumed continuation of trends in substantial hardwood encroachment after harvest of pine stands on NIPF lands, which has been raised as an issue for several decades (e.g., Alig 1985, Knight 1973). Gains include reversions to timberland from abandoned agriculture land that seed in as pine in some cases, and some transitions from oak-pine to natural pine dominance in a stand. Natural pine areas are projected to decrease in the Southeast and on forest industry lands in both subregions, but these losses are offset by increases on NIPF timberlands in the South Central subregion.

The largest projected area decrease is for the upland hardwood type, with an 18-million-acre or 26-percent loss projected by 2050. A combination of factors underlies the projected reduction: conversion to nontimberland land uses, conversion to pine plantations, and transitions to other types including oak-pine. The projected rate of reduction in upland hardwood area slows considerably after 2010–15, as incentives for conversion to pine plantations lessen with stable to falling softwood prices. The projection represents a change from long-term historical trends for the South. However, hardwoods will continue to dominate the forested landscape of the South. Hardwood forests in 2050 are projected to cover about one-half of the southern private timberland base, twice the amount for planted pine in the region. The FIA data concerning type transitions after harvests of pine plantations further suggest that many plantation acres are currently reverting to naturally regenerated forest types, ranging from 70 percent of the final harvested plantations on NIPF private timberlands in the South Central subregion to 34 percent on industry timberlands in the Southeast subregion.

The forest type dynamics of the region vary by ownership and subregion. Most of the planted pine is projected to be gained in the South Central subregion, and larger areas of planted pine are projected for the forest industry than for other private or miscellaneous corporate owners in both the Southeast and the South Central subregions. The greatest loss of natural pine is projected for the Southeast subregion, particularly on other private timberlands. The largest changes in the area of oak-pine are projected decreases on forest industry timberlands, especially in the South Central subregion. The total area of lowland hardwood was projected to remain relatively constant at the regional level, but the area of lowland hardwood was projected to increase on NIPF timberlands in the South Central subregion and decrease in all other ownership/subregion categories.

Chapter 3: Rocky Mountains Region

Introduction

The Rocky Mountains region consists of the Intermountain and Great Plains subregions (fig. 1, table 1). The region covers a vast area, about 742 million acres or about one-third of the entire Nation and encompasses a variety of landforms with diverse climatic conditions. Scenic landscapes of the Intermountain subregion stretch from the Canadian border to the Mexican border, and from the plains westward into the mountainous states. The Great Plains contain vast treeless areas and rangelands.

The Great Plains can have hot, dry summers and cold winters, especially in the northern tier of states (USDA Forest Service 1989). Periodic droughts are not uncommon, and precipitation can be sparse. The Intermountain states also contain many dry areas, with extensive areas of arid desert in Arizona and New Mexico. Winters tend to be cold and dry, and summers warm to hot, where moisture is often the limiting factor for plant growth. In some areas, particularly the drier regions, soils (e.g., limestone soils) can have a profound effect on plant community composition (Covington et al. 1994).

The relatively large Rocky Mountains region contains about one-third of the Nation's land area and about one-fifth of the U.S. forest land, but contributes only 5 percent of the U.S. timber harvest. Approximately three-quarters of the region's forest land is publicly owned, has lower productivity on average than most other regions, and owner objectives often center on nontimber objectives. About half of the forest land in the region is classified as timberland (see "Glossary" for definitions of forest land and timberland) (Smith et al. 2001).

Forest Cover Situation

Overall, softwood types are the dominant forest cover on timberland in the region (table 2). Five forest cover types totaling about 112 million acres compose about 80 percent of the forest land in the Rocky Mountain states: pinyon-juniper, Douglas-fir, fir-spruce, ponderosa pine, and lodgepole pine (fig. 26). The pinyon-juniper cover type is a major forest type as well as a rangeland ecosystem, occurring as a relatively uniform cover type, with low tree species diversity (fig. 27). This pinyon-juniper cover type occupies more than 45 million acres, generally at elevations (4,500 to 7,500 feet) above the desert floor and below ponderosa pine. However, less than one-half million acres are classified as timberland (fig. 27), because of the relatively low timber productivity of this cover type. The pinyon-juniper ecosystem is found frequently on dry plateaus and broken tablelands, such as in western Colorado, Utah, Nevada, New Mexico, and Arizona (USDA Forest Service 1989).

The dominant forest types in the Rocky Mountains region are pinyon-juniper, Douglas-fir, fir-spruce, ponderosa pine, and lodgepole-pine.

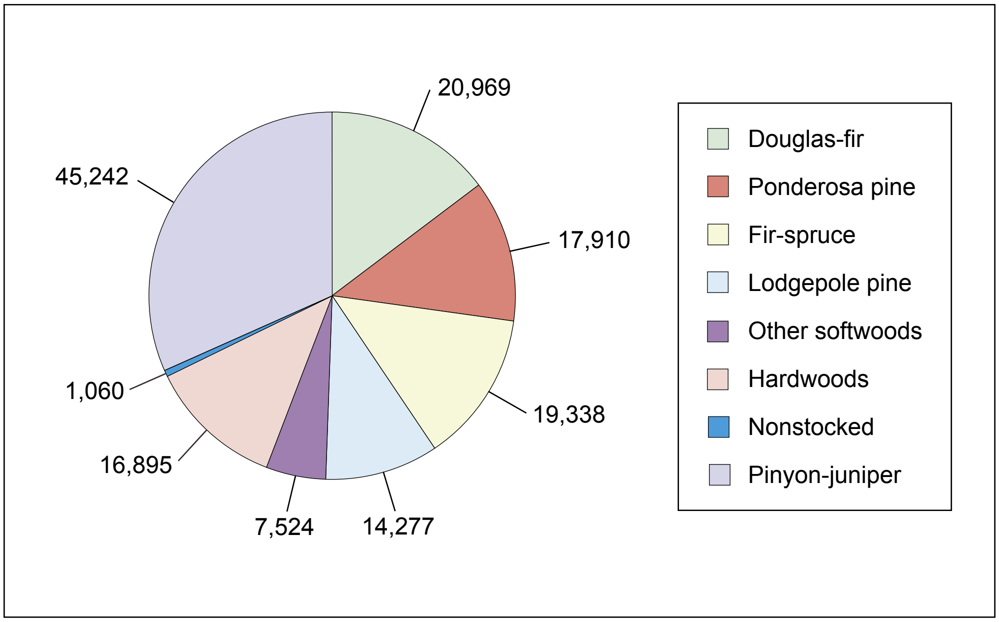


Figure 26—Area of forest land (thousand acres) by forest cover type in the Rocky Mountains region, 1997 (Smith et al. 2001).

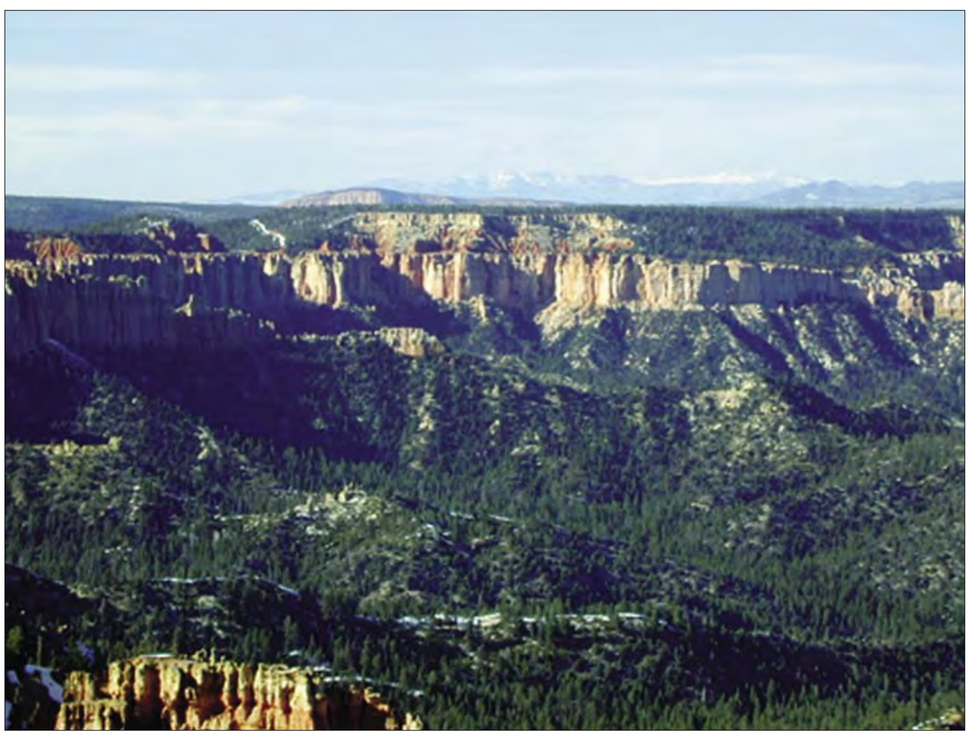


Figure 27—Pinyon-juniper covers large areas in the Rocky Mountains region.

The four forest cover types that occupy the next largest areas are Douglas-fir (21 million acres), spruce-fir (19 million acres), ponderosa pine (17 million acres), and lodgepole pine (14 million acres). These forest cover types make up the bulk of timberland in the region. In terms of timber production, the Douglas-fir and ponderosa pine types are the most important.

Dense conifer stands are not uncommon in parts of the region, such as pure stands of lodgepole pine that have little, if any, understory vegetation (Hessburg et al. 2000). Fire-related concerns about overstocked forest stands with small-diameter suppressed trees are not new (e.g., Cooper 1960); however, higher than average human population growth and associated development (Alig et al. 2004) within wildland-urban interfaces have increased risk from forest fires to private property and human life. Future impacts on conifer forest cover types are notably uncertain with respect to forest fire extent and policy-related interventions.

The largest area gains in the Rocky Mountains region between 1953 and 1997 were for Douglas-fir, fir-spruce, and the western hardwood forest types.

Hardwood species have wide ranges throughout much of the Rocky Mountains region (fig. 28). Timberland hardwoods consist primarily of two species: quaking aspen (*Populus tremuloides* Michx.) and cottonwood (*Populus* spp.). At higher elevations, aspen is usually found as small patches or groups of patches punctuating the mountainsides. However, in Colorado and Utah, where two-thirds of the aspen is located, there are rather extensive areas. At lower elevations, the hardwoods in the region are typically represented by cottonwoods along streambanks and in low valleys and by oaks (*Quercus* spp.) in woodlands.

The widespread distribution of quaking aspen forests on the region's high plateaus and mountain ranges and their importance for many wildlife species make these forests a significant biotic community. Although aspen is considered a climax species on some sites, it is usually seral to conifers (fig. 29). This replacement is gradual and can take from 100 to 200 or more years. If an aspen stand is within a mixed-conifer forest, however, conifers can become established within a single decade. Because aspen stands are different from conifer stands, they can add to landscape diversity and wildlife habitat. Although aspen stems are short lived and snags do not stand long, the wood is soft, often decayed, and therefore useful to cavity-dependent species. Young sprouts are heavily browsed by elk and deer.

Aspen stands are in decline on the Colorado Plateau in parts of Arizona and New Mexico. The combination of modern fire suppression and a steady increase in elk herbivory has prevented aspen regeneration in many forests, with conifer understories now widely overtopping aspen stands. Aspen clones are able to persist in a suppressed state in the understories of conifers for many years, but without major fires, aspen stands may continue to decline.

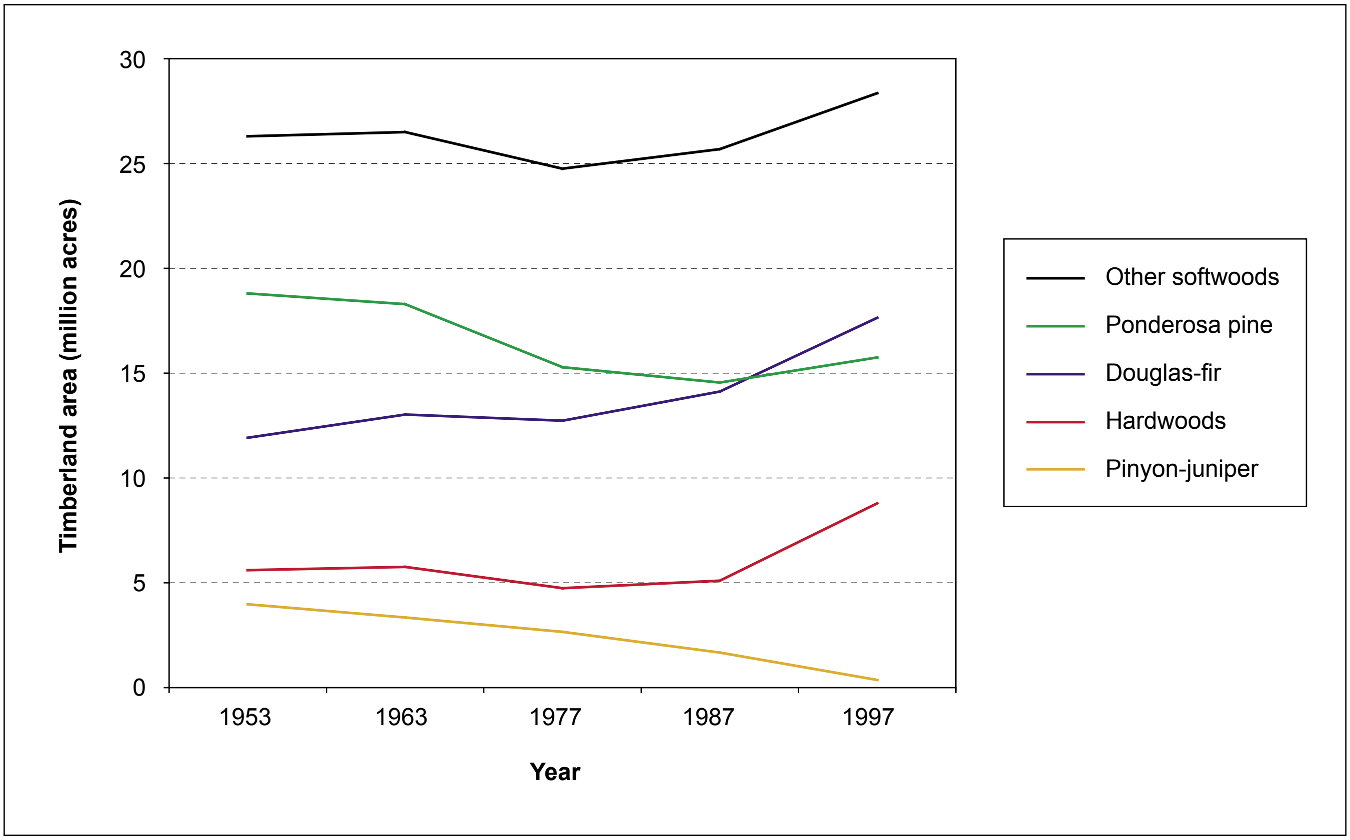
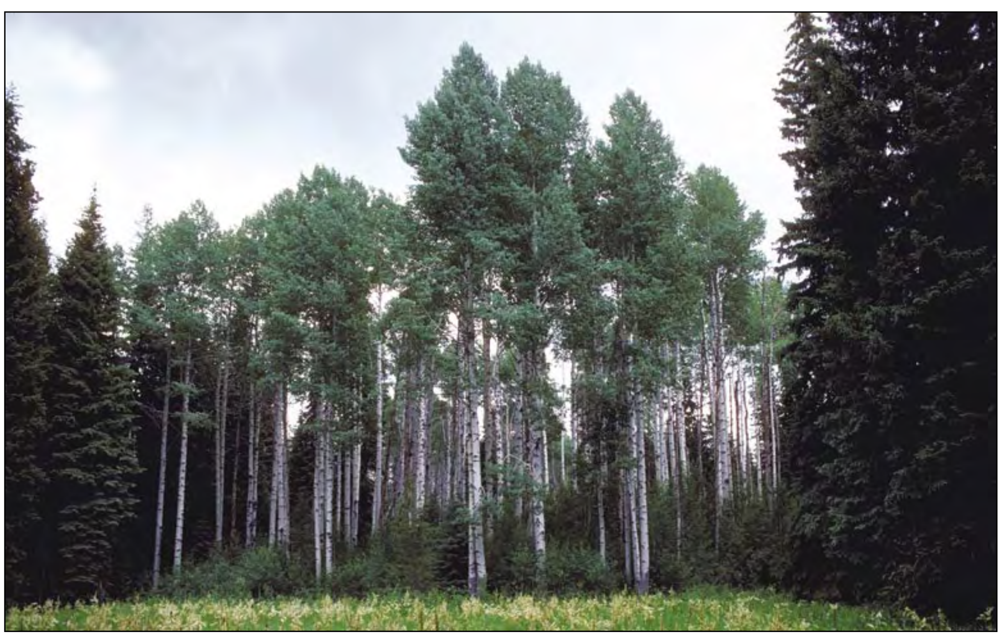


Figure 28—Area trends for major forest cover types on timberland in the Rocky Mountains region, 1953 to 1997 (Smith et al. 2001).



Dave Powell, USDA Forest Service, www.forestryimages.org

Figure 29— Without major disturbances, some aspen stands are succeeded by conifer stands in the Rocky Mountains region.

From 1962 to 1985–87, the mixed-conifer forest type increased by 1.0 million acres, or 81 percent. Ponderosa pine decreased slightly in acreage, and aspen decreased by 46 percent (Johnson 1996). Many changes occur as such forests become denser. The character of forest fires changes. They now burn less frequently but are high-intensity, stand-replacing fires (Covington and Moore 1994). Forests in the southwest have lost much of their diversity, but they have far more trees today than before.

Forest cover types with the largest area gains on the region's timberland base between 1953 and 1997 were Douglas-fir, fir-spruce, and the western hardwood types (Smith et al. 2001). The largest area reductions were for the lodgepole, pinyon-juniper, and ponderosa-Jeffrey pine types. Overall, the biggest area change was the approximately 6-million-acre increase in the Douglas-fir type, with that type now the most common type on the region's timberland.

Projections

Total timberland area in the Rocky Mountains region is projected to fall slightly from 71.0 million acres in 1997 to 70.9 million acres in 2050 (Alig et al. 2003). The projected decrease is largely on the NIPF ownership. Substantial areas of privately owned forests have been subdivided for home sites and ranchettes, particularly in the mountainous areas of Montana, Idaho, and Colorado. Above-average growth in population has contributed to more people on the region's landscape.

Softwoods are projected to remain the dominant forest type in the Rocky Mountains region, with the area of Douglas-fir projected to increase.

Overall, the projected changes in forest cover types are relatively small compared to those for some other regions (e.g., South) (table 3, figs. 30 and 31). Softwood types are projected to remain dominant on most of the region's timberland.

In both the northern and southern portions of the Intermountain subregion, the dominant projected trend is an increase in the area of the Douglas-fir type (figs. 30 and 31). This increase is partially offset by decreases in the areas of pine, fir, and spruce forest types. By subregion, the projected decreases are consistent for the other coniferous types, except that area of ponderosa pine is projected to increase in the southern subregion.

Area of hardwoods is projected to increase in the northern portion of the Intermountain subregion, primarily on NIPF timberlands. In the southern portion, hardwood area is projected to decline.

Projected area changes by forest cover type are in the same direction for forest industry and NIPF private lands, with the exception of lodgepole pine. Lodgepole pine is projected to decrease by more than 50 percent on NIPF timberlands and slightly increase on forest industry lands.

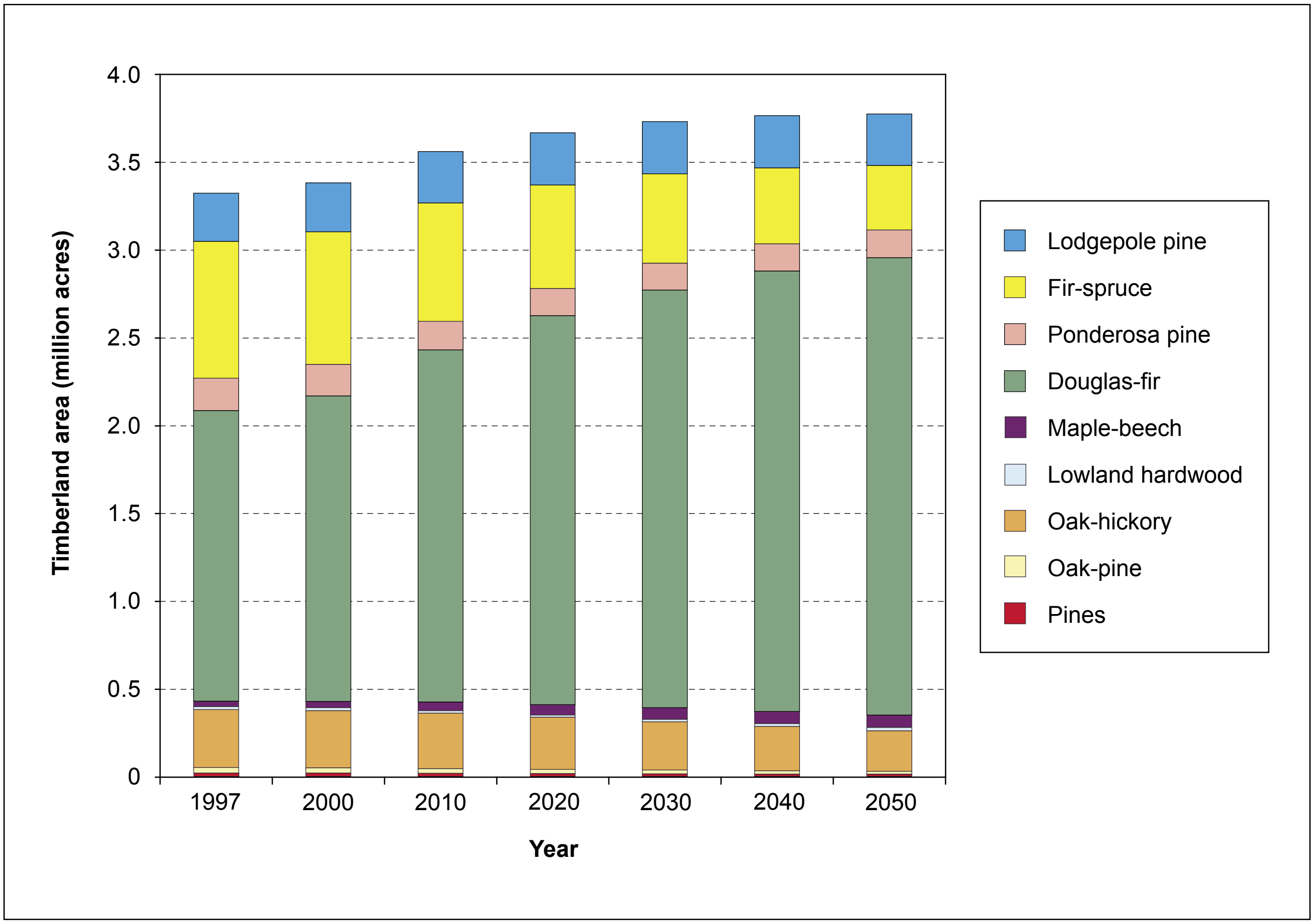


Figure 30—Projected area changes for forest cover types on forest industry timberlands in the Rocky Mountains region, 1997 to 2050.

At the time of the last RPA assessment, one issue in the Rocky Mountains region involved the aspen forest type and utilization trends for a forest cover type that is highly valued in some areas for fall foliage and other amenities. Since that time, oriented strand board capacity has dropped substantially; where there were once four operational oriented strand board plants in the U.S. West, now there are none (Ince 1999, 2000). At a broader level, there has been no capacity growth for wood pulp in the West for some time, and some mills have closed over the past decade or so (Ince 1999, 2000). Pulp mills in the West primarily use softwood mill residues, in contrast to timber harvests specifically for pulpwood (e.g., aspen) as in the Lake States.

Timber harvest in the Rocky Mountains represented less than 9 percent of the total U.S. softwood harvest in 1996, and even less of the hardwood harvests. The volume of total timber harvest is projected to drop slightly by 2050, mainly

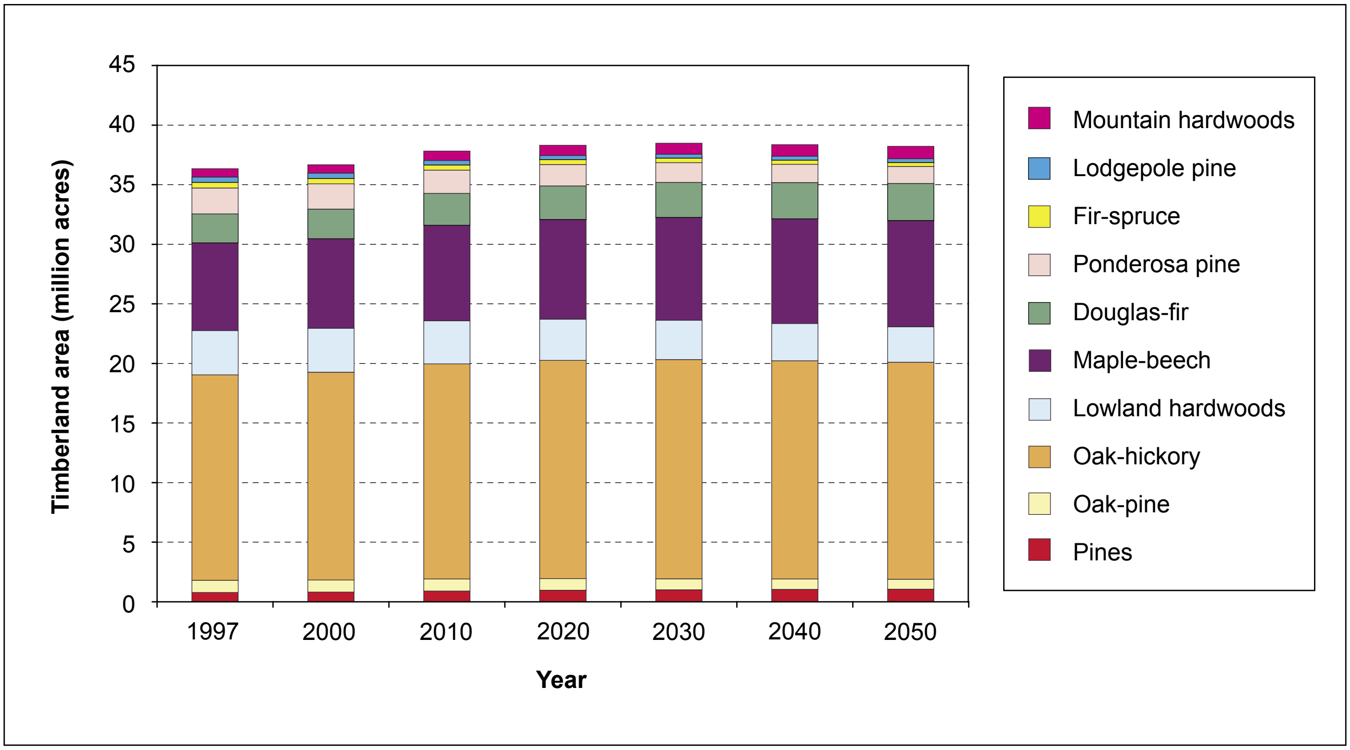


Figure 31—Projected area changes for forest cover types on nonindustrial private forest timberlands in the Rocky Mountains region, 1997 to 2050.

in the southern Rocky Mountains (Haynes 2003). Compared to regions such as the South, timber harvest over the large Rocky Mountain region is typically less frequent and does not affect forest cover on as high a percentage of forested acres.

Decreased fire frequency owing to grazing and fire suppression triggered a shift to forests with very high tree densities (fig. 32), which in turn contributed to destructive forest fires. Options to deal with these changes include prescribed fire, thinning, and timber harvest to mimic natural disturbances and conditions. However, there are barriers to implementing these activities on a scale large enough to have a significant benefit. In the inland West, Covington et al. (1994) anticipate increased tree seedling establishment, intensified competition among established trees, further deterioration of tree vigor, and increasing tree mortality from insects, diseases, drought, and fire. The fire risks are related to an acceleration of historical changes that include increased forest fuel accumulations, lengthened fire seasons, and intensified burning conditions.

Figure 32—Many forest stands in the Inland West have high numbers of trees per acre and are prone to fire risks.

Summary, Rocky Mountains Region

The region covers about one-third of the entire Nation and encompasses a variety of landforms and has diverse climatic conditions, including some large areas with sparse or no tree cover. Forest cover types with the largest area gains on the region's timberland base between 1953 and 1997 were Douglas-fir, fir-spruce, and the western hardwood types. Largest area reductions were for the lodgepole, pinyon-juniper, and ponderosa-Jeffrey pine types. Overall, the biggest area change was the approximately 6-million-acre increase in the Douglas-fir type, with that type now the most common type on the region's timberland.

The Douglas-fir type also is projected to have the largest area increase in the future. This increase is partially offset by decreases in the areas of pine, fir, and spruce forest types. Hardwood area is projected to increase in the northern part of the region but decrease in the southern portion.

Chapter 4: Pacific Coast

Introduction

The Pacific Coast region has three Forest and Rangeland Renewable Resources Planning Act (RPA) subregions: Pacific Northwest consisting of Oregon and Washington, Pacific Southwest consisting of California and Hawaii, and Alaska[1] (fig. 1, table 1). Latitude and environmental conditions vary widely across the region; e.g., boreal conditions of Alaska versus tropical conditions of the island state of Hawaii. Extremes of environmental conditions owing to the latitudinal differences are moderated in some areas and exaggerated in others by influences of ocean currents, prevailing winds, and landform (USDA Forest Service 1989). However, annual precipitation varies across the region from 10 inches or less in the arctic zone of Alaska's northern and western coastal plains to more than 150 inches in places in southern coastal Alaska and western Washington.

The fir-spruce cover type is the most extensive forest cover type in the Pacific Coast region.

In the maritime zone are some of the tallest trees in the world, and the most productive coniferous forests in the Northern Hemisphere. The redwood belt of California, the spruce and hemlock forests of coastal Alaska, and the portion of the Pacific Northwest west of the crest of the Cascade Range in Oregon and Washington (Pacific Northwest West subregion) are within the maritime zone (USDA Forest Service 1989).

Growing conditions for forests differ widely within the region, as forests of eastern Oregon, eastern Washington, and eastern California are less productive on average than those in the maritime zone. The better sites in the eastern parts of these states, however, are quite productive, yielding high-quality ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), western larch (*Larix occidentalis* Nutt.), true firs (*Abies* spp.), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and inland Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) (USDA Forest Service 1989).

In 1997, Douglas-fir was the most common forest type on both forest industry and NIPF timberlands in the Pacific Northwest West subregion.

Approximately two-thirds of the region's forest land is publicly owned. More than half of the region's forest land has a timber productivity rating below the threshold for timberland, much of that on public forest land in Alaska. Overall, public ownership accounts for 66 percent of forest land in the region, forest industry ownership for 6 percent, and nonindustrial private forest (NIPF) ownership for 28 percent (Smith et al. 2001).

[1] Alaska and Hawaii are included in some tables with historical data, but were excluded from the modeling in the RPA timber assessment, and forest cover projections were not prepared for those two states. Together, the two states contain 2.6 percent of total U.S. timberland area; although Alaska has a relatively large forest land base, more than 90 percent of that forest land either has productivity too low to be classified as timberland or is reserved.

Forest Cover Situation

Overall, softwood types are the dominant forest cover on timberland in the region (table 2). In terms of area, the fir-spruce cover type is the most extensive forest cover type in the Pacific Coast region, covering more than 50 million acres (fig. 33). Most of this is in Alaska and is below the productivity cutoff for timberland because of harsh climate, permafrost, shallow or poorly drained soil, or other environmental factors. The fir-spruce cover type in Alaska is usually associated with hardwoods, or follows hardwoods in ecological succession. Together, fir-spruce and hardwood forests cover more than 100 million acres, mostly in Alaska's interior (USDA Forest Service 1989). In Oregon, Washington, and California, the fir-spruce cover type occupies about 10 million acres, most of which meets the timberland productivity standard.

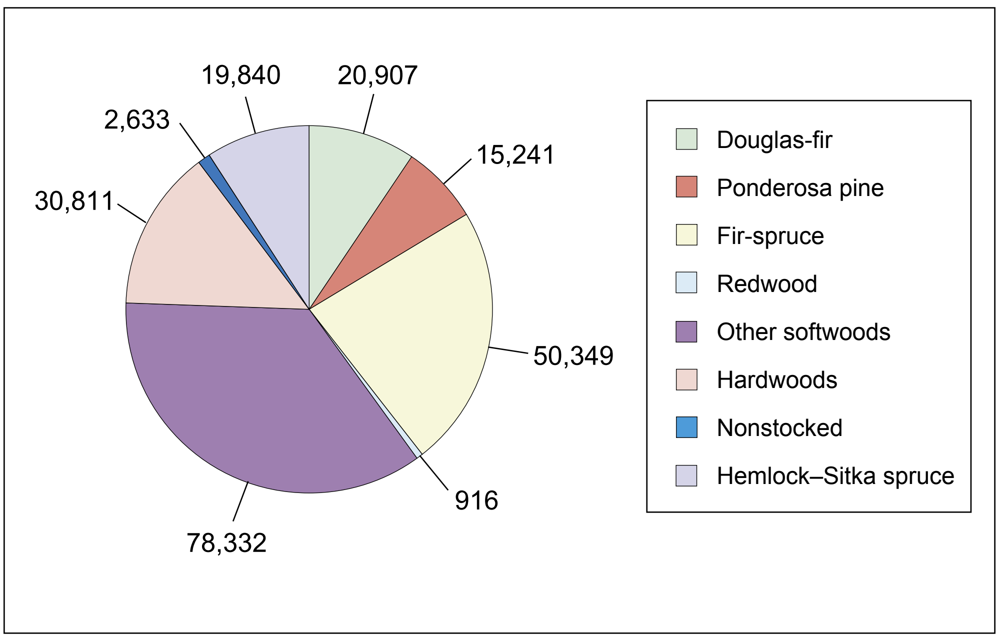


Figure 33—Area of forest land (thousand acres) by forest cover type in the Pacific Coast region, 1997 (Smith et al. 2001).

The most important forest type, in terms of timber production, in the region is Douglas-fir. This cover type occupied more than 20 million acres in 1997 (Smith et al. 2001). The best sites are capable of yielding more than 200 cubic feet per acre per year of wood, and more than one-half of the cover type's area can yield more than 120 cubic feet (fig. 34).

Figure 34—Douglas-fir is an important commercial timber species in the Pacific Coast region, which contains some of the most productive forests in the world.

The Douglas-fir forest type is managed under a broad range of management regimes, from custodial management to plantings with genetically improved stock, precommercial thinning, and fertilization resulting in substantial differences in growth by treatment (Haynes 2003). The dominance of the Douglas-fir forest type and species in the region is a result of the species' high growth capacity, its adaptability to high-intensity management (e.g., its ability to reforest clearcuts), and the high economic value of its wood. There are a number of factors influencing the composition of Douglas-fir stands, if not the total area in this forest type. For example, the increased diversity of seedlings being planted and changes in management intensities (such as rotation lengths and vegetation control) are influencing the composition and structure of trees within this forest type.

The largest changes in forest type areas in the Pacific Northwest West between 1977 and 1997 were the loss of red alder and the gain of Douglas-fir.

In 1997, Douglas-fir was the most common forest type on both forest industry and NIPF private timberlands in western Oregon and western Washington (Pacific Northwest West subregion). Douglas-fir accounted for 55 percent of the private timberland, whereas hemlock-spruce occupied 14 percent, red alder occupied 13 percent, other hardwood occupied 10 percent, and other softwood occupied 5 percent of the private timberland. The majority of Douglas-fir, 73 percent, and hemlock-spruce, 83 percent, were on forest industry lands, and the other forest types were more evenly distributed between the private owner groups.

Softwood types are projected to remain the dominant forest cover type in the Pacific Coast region, as more area is planted to Douglas-fir.

The Douglas-fir cover type is a collection of many different plant communities. The dominant species within the Douglas-fir cover type were generally the same between ownerships, but the relative importance of the species differed. Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) was the dominant species, occupying 75 percent of the timber volume of forest industry and 74 percent of the timber volume of NIPF stands. Western hemlock and red alder (*Alnus rubra* Bong.) were the next most abundant species in the Douglas-fir forest type.

The forests of the Pacific Northwest West subregion are continually changing in response to harvesting patterns and natural succession (fig. 35) (Alig et al. 2000c). The forest dynamics of the region are in a transitional stage, with some historical patterns being altered by current economic and social factors, such as ownership patterns, timber markets, management regulations, and changing management objectives. Before the 1990s, a large proportion of the timber harvested in the region came from national forests, but federal regulations have greatly reduced the allowable cut on federal lands to allow for protection of the northern spotted owl (*Strix occidentals caurina*) and other species deemed dependent upon late-successional habitat for parts of their life cycles. As the level of federal timber harvests decreased, the importance of timber harvested from private lands increased. Timber harvests on federal lands have dropped sharply since the early 1990s (figs. 36 through 38), and some demands have shifted to private timberlands, leading to shorter timber rotations and more opportunities for cover type change at time of regeneration (Haynes 2003).

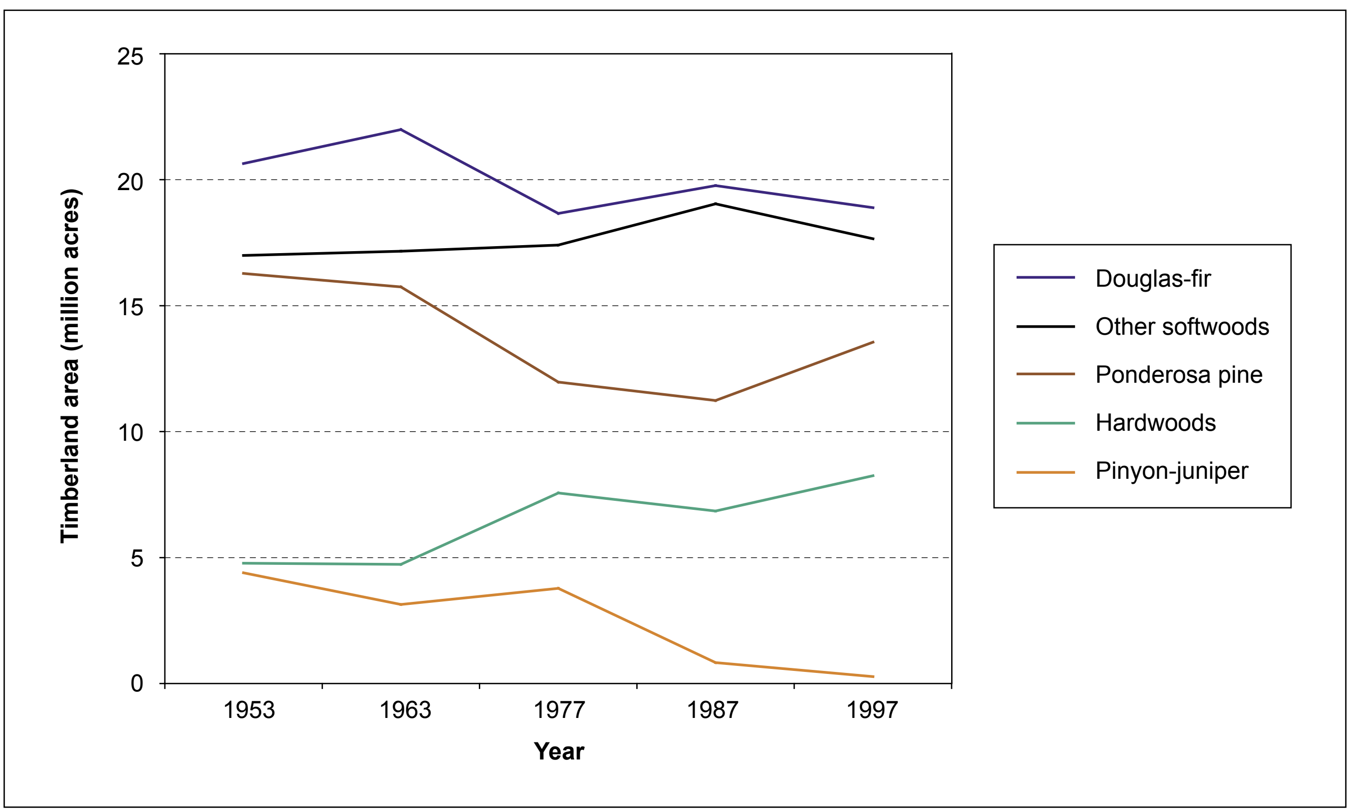


Figure 35—Area trends for major forest cover types on timberland in the Pacific Coast Northwest (Oregon and Washington), 1953 to 1997 (Smith et al. 2001).

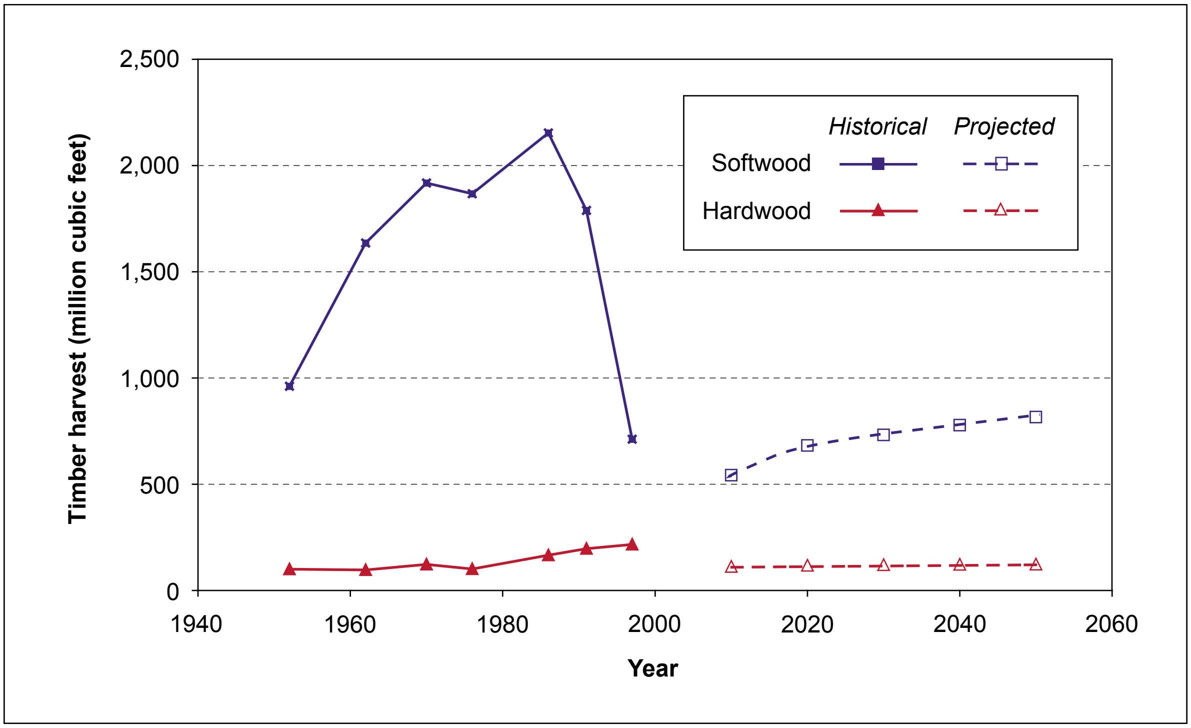


Figure 36—Trends in timber harvest volumes from public and private timberlands in the Pacific Northwest (Oregon and Washington), 1953 to 1997, with projections to 2050.

Forest cover types with the largest area gains on the region's timberland base between 1953 and 1997 were two with relatively small areas: fir-spruce and the western hardwood types (Smith et al. 2001). The region had a net loss of 3.3 million acres of timberland, with the largest area reductions for the ponderosa-Jeffrey pine and western white pine types. Reclassification of timberland to another forest-land class (e.g., reserved forest land) has affected area changes for forest types on timberland. The Douglas-fir type has been affected by such changes, but in 1997 was still the most common type on the region's timberland, covering 26 percent.

The dominance of Douglas-fir on private lands in the Pacific Northwest West is projected to continue for at least the next 50 years.

The largest changes in forest type areas on private timberlands in the Pacific Northwest West subregion between 1977 and 1997 were the loss of red alder and the gain of Douglas-fir (Smith et al. 2001). The trends and magnitudes of historical changes varied by ownership. Other hardwood area increased on forest industry timberlands and decreased on NIPF timberlands. The forest industry lost significantly more western hemlock-Sitka spruce and gained significantly more Douglas-fir than the NIPF owners.

Timber demand, competing land uses, technology, and public policies also have influenced the forest type dynamics of the region. The increasing demand for timber on regional and global markets has placed high values on many of the forest products and provides incentives for forest management that produces trees with

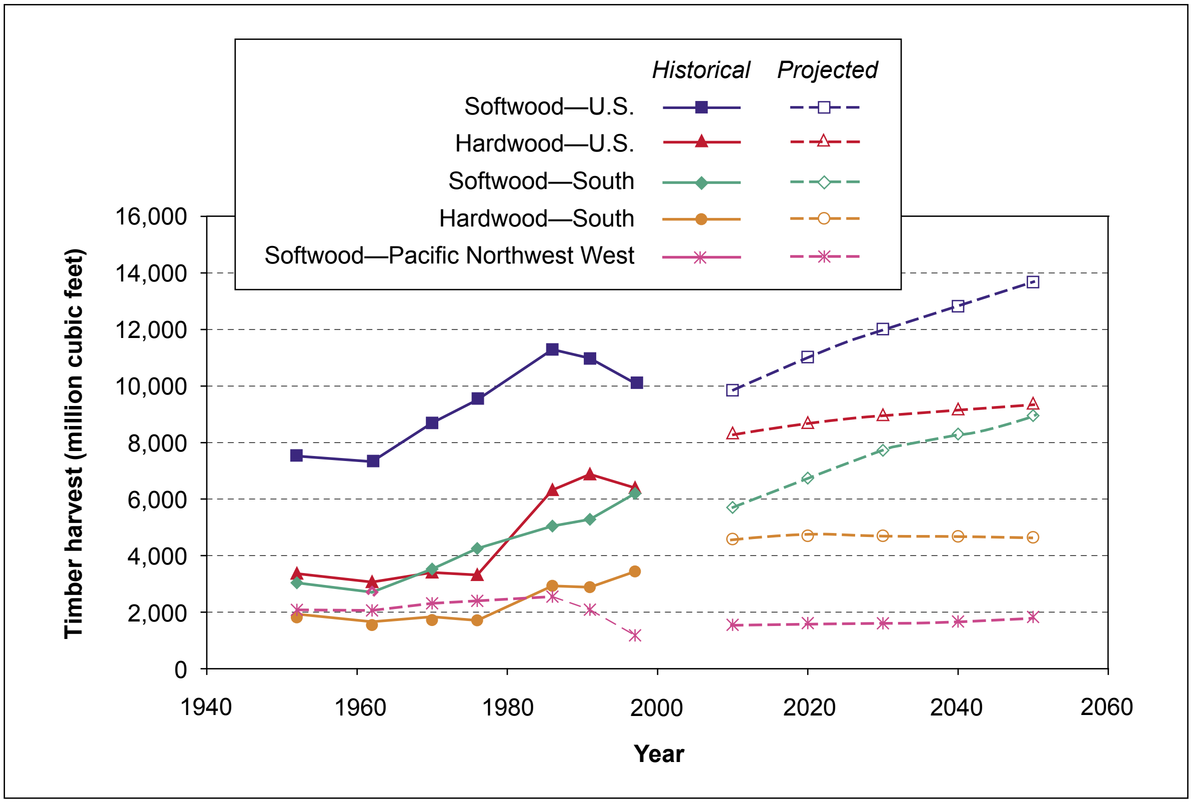


Figure 37—Trends in timber harvest by selected U.S. regions, 1953 to 1997, with projections to 2050.

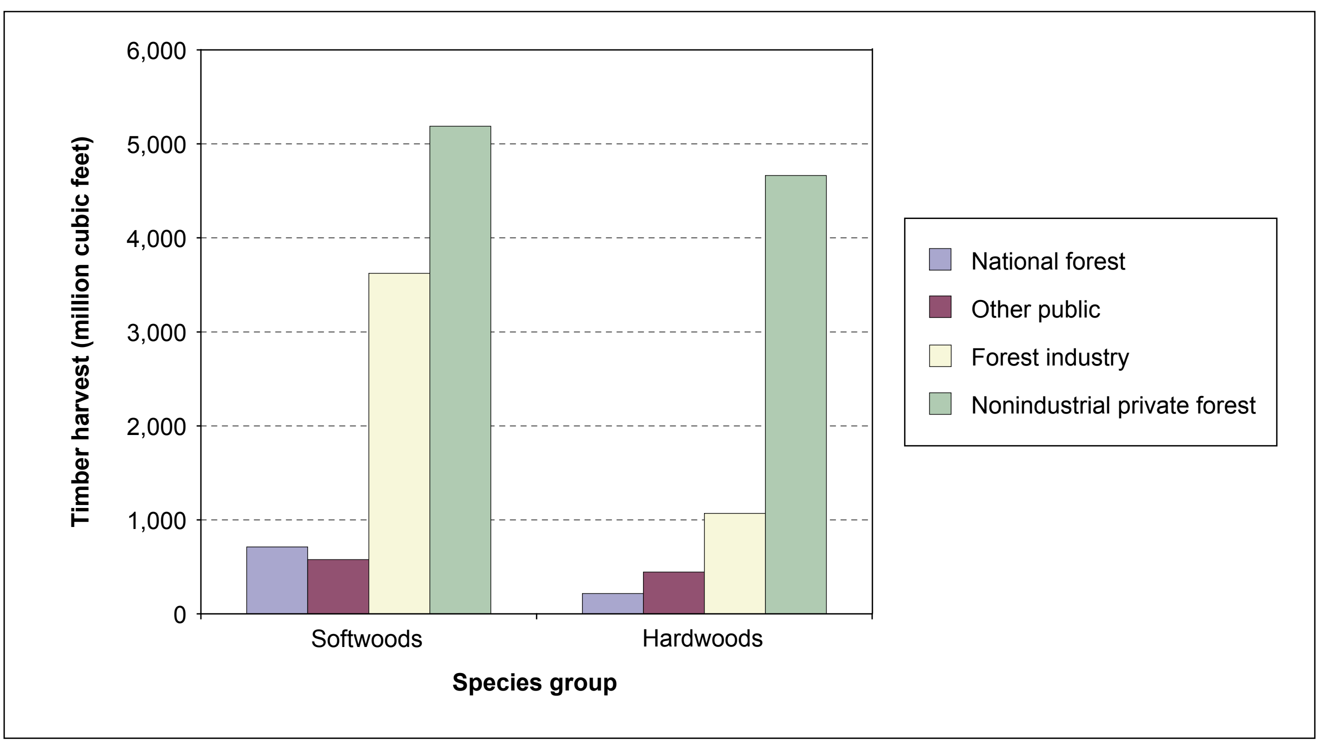


Figure 38—U.S. timber harvest by major forest ownership and species group (1997).

specific quality and size attributes. Residential and commercial land uses are the greatest sinks of timberland, and these pressures will be increasing as the population of the region increases. Technologies, such as genetically improved seedlings, are helping forest landowners meet their objectives. Public policies have provided incentives and disincentives for specific forest management practices. For example, there are laws in Oregon and Washington that limit clearcut sizes and require specific levels of regeneration following harvest activities.

Projections

Total timberland area in the Pacific Coast region is projected to fall from 72.2 million acres in 1997 to 69.3 million acres by 2050. As in the Rocky Mountains, most of the projected reduction is for the NIPF ownership (Kline and Alig 2001). Much current timberland in the Pacific Coast region is located on lands where forestry has a competitive advantage or is a residual land use owing to physiography. Projected changes are smaller than historical ones. The projected net area changes reflect direct conversion of timberland to urban and developed uses and other acres converted to replace cropland lost to urban and developed uses.

Overall, softwood types are projected to remain the dominant forest cover types on timberland in the region (table 3). The most substantial cover type changes in the Pacific Coast region are projected to occur on forest industry lands, as more area is planted to Douglas-fir, especially in the Pacific Northwest West subregion (figs. 39 through 44). These changes are stimulated by the increased value of Douglas-fir. Douglas-fir is the most common forest type for stands to transition to regardless of harvest type. These transition rates were generally higher for the forest industry than for NIPF owners. Douglas-fir also had the highest probability of remaining in the same forest type following a given disturbance, except for partial harvests on forest industry timberlands.

Douglas-Fir in the Pacific Northwest West Subregion

Douglas-fir is the most common forest type in the Pacific Northwest West subregion, and this dominance on private lands is projected to continue for at least the next 50 years (figs. 41 and 42). The forest industry is the principal owner of this forest type, and the area of Douglas-fir on their timberlands is projected to increase. Much of the increase in the area of Douglas-fir on the forest industry timberlands is transitioning from western hemlock-Sitka spruce and red alder and other hardwoods following final harvests.

Although the area of Douglas-fir is projected to have a net increase on private timberlands, the net area change of the Douglas-fir cover type on NIPF timberlands

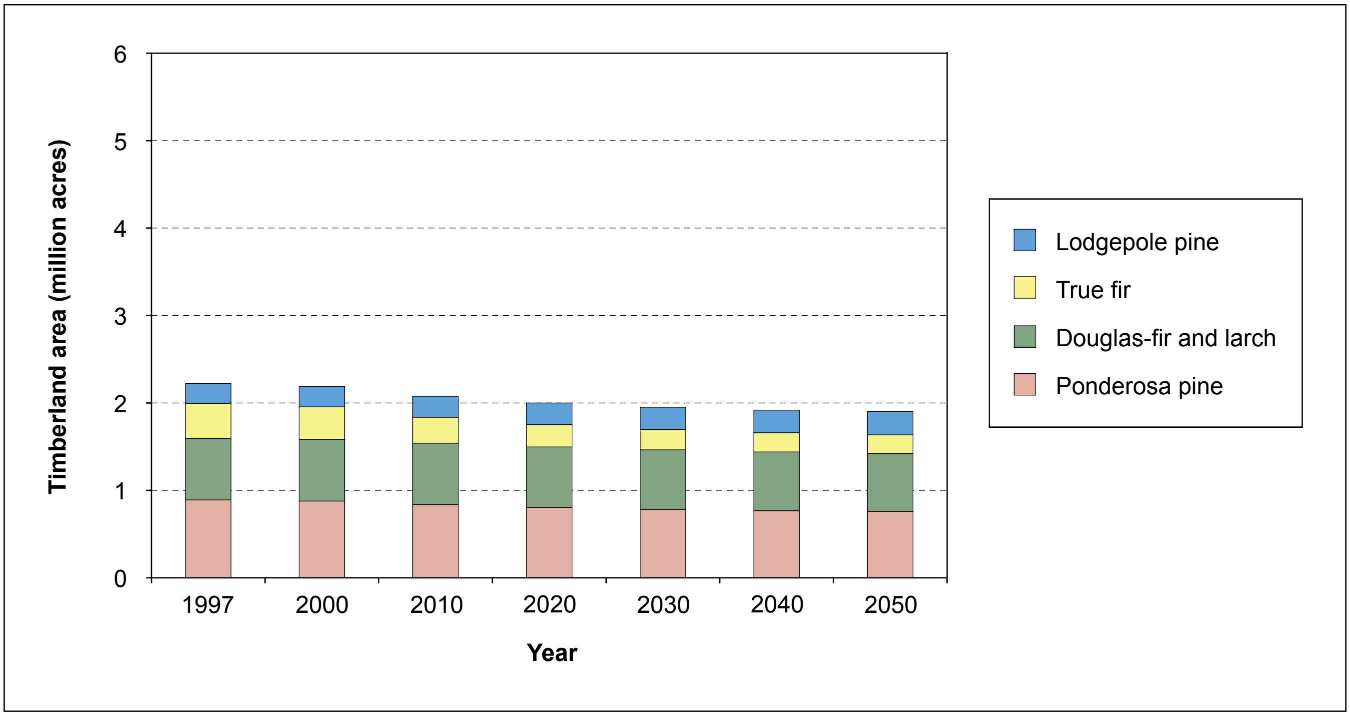


Figure 39—Projected area changes for forest cover types on forest industry timberlands in the Pacific Northwest East subregion, 1997 to 2050.

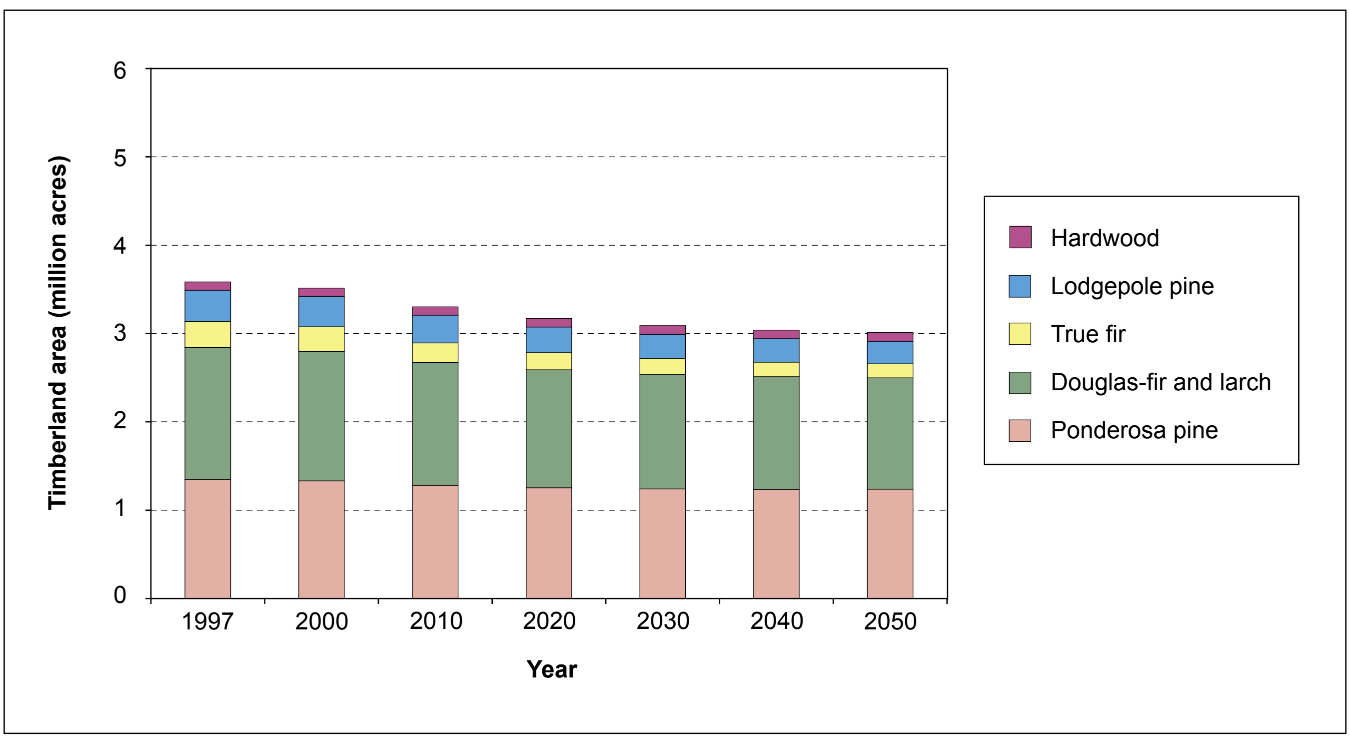


Figure 40—Projected area changes for forest cover types on nonindustrial private forest timberlands in the Pacific Northwest East subregion, 1997 to 2050.

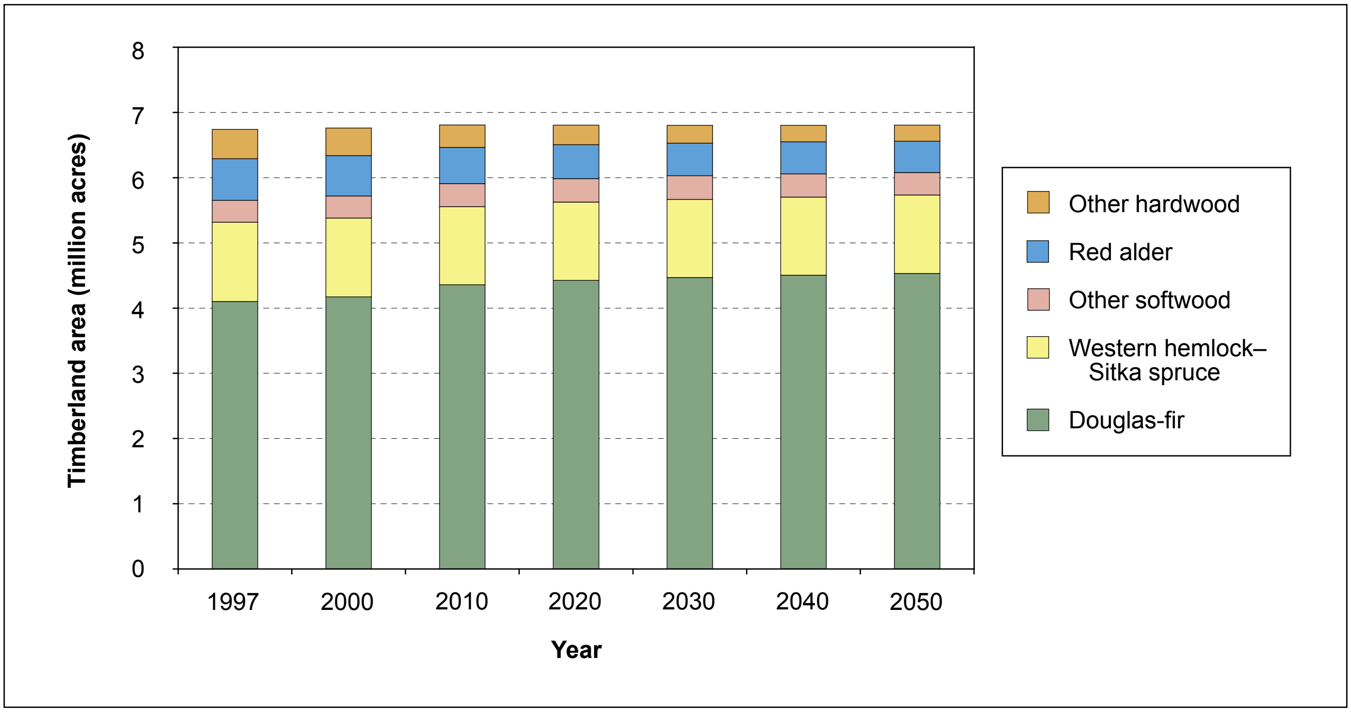


Figure 41—Projected area changes for forest cover types on forest industry timberlands in the Pacific Northwest West subregion, 1997 to 2050.

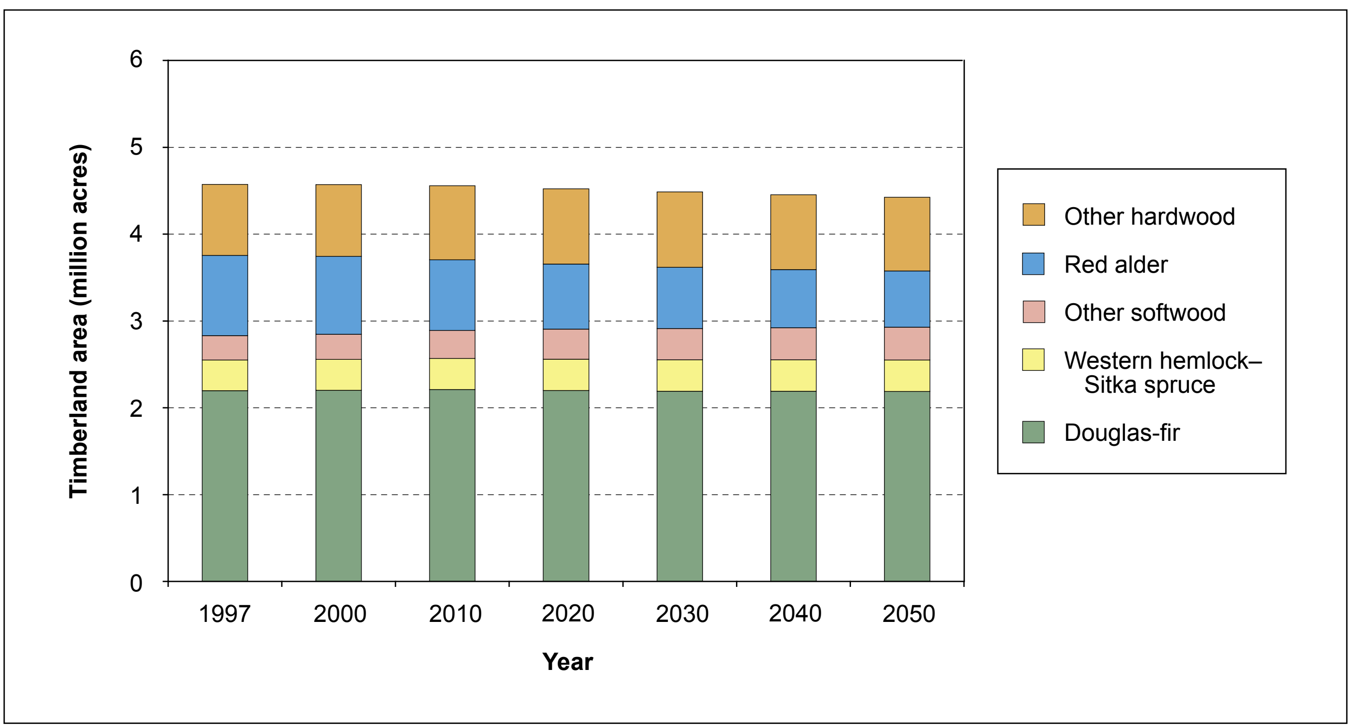


Figure 42—Projected area changes for forest cover types on nonindustrial private forest timberlands in the Pacific Northwest West subregion, 1997 to 2050.

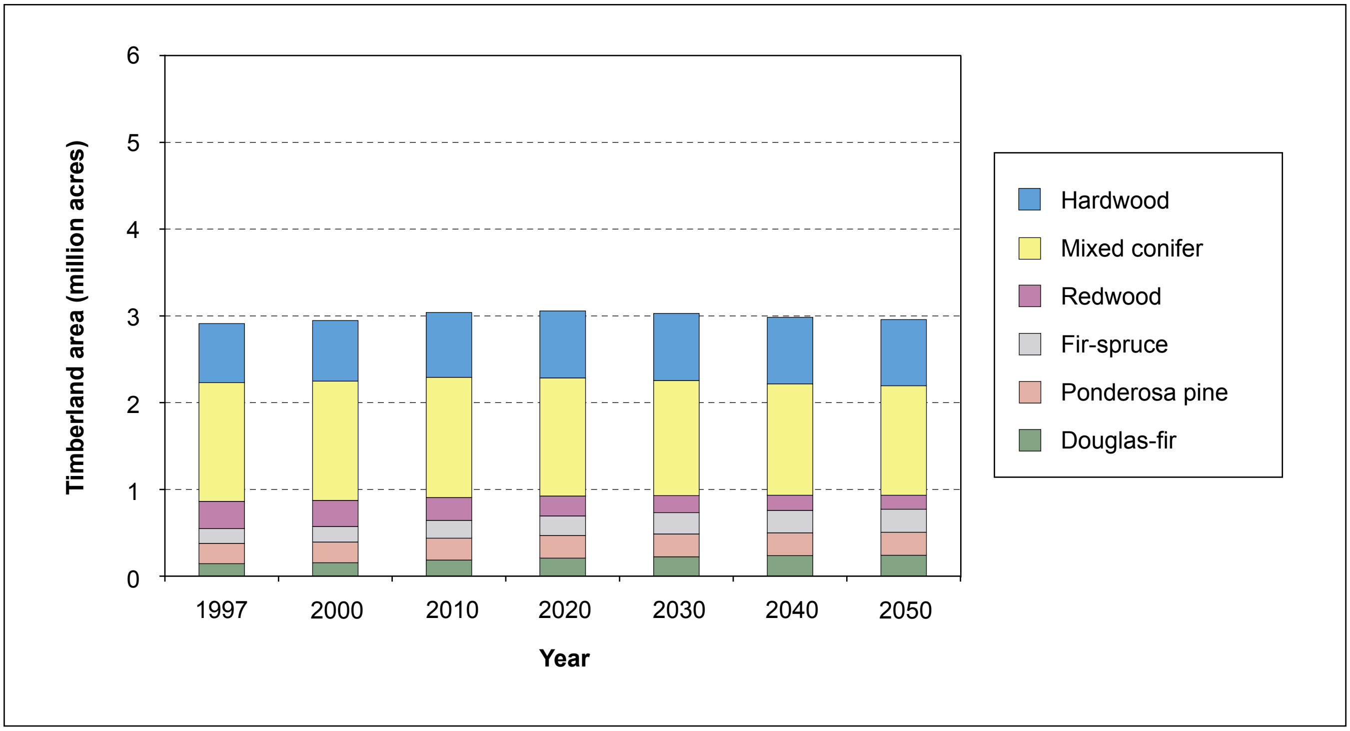


Figure 43—Projected area changes for forest cover types on forest industry timberlands in the Pacific Southwest subregion, 1997 to 2050.

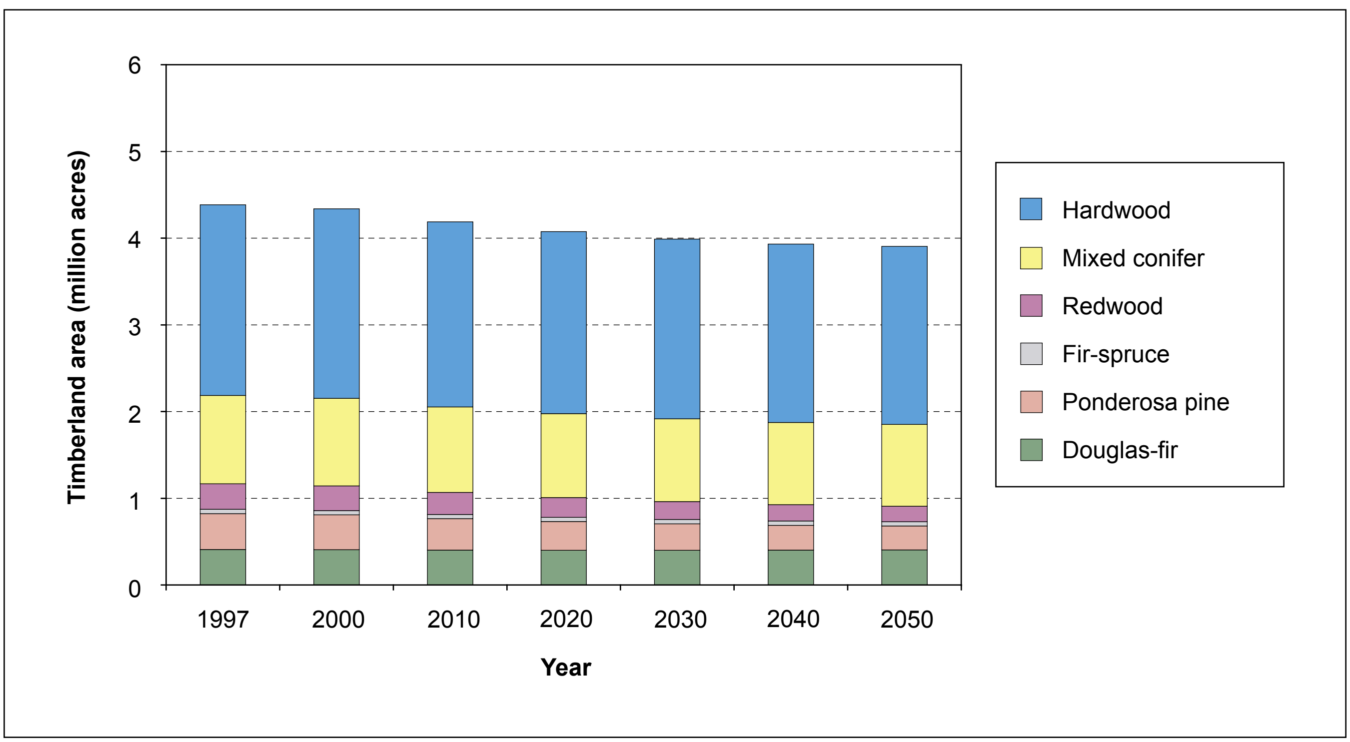


Figure 44—Projected area changes for forest cover types on nonindustrial private forest timberlands in the Pacific Southwest subregion, 1997 to 2050.

between 1997 and 2050 is a small decrease. Some of the NIPF Douglas-fir is being lost to nontimberland land uses, such as residential areas (Alig et al. 2000c, Kline and Alig 2001, Zheng and Alig 1999), but most of the losses result from transitions to the hardwood forest types following final and partial harvests. This may result from insufficient regeneration efforts following harvests or from changing landowner objectives. Insufficient regeneration is probably only a partial answer because of the regeneration regulations in Oregon and Washington that require, to varying degrees, the establishment of a number of free-to-grow trees within a specified period following final harvests. The high numbers of Douglas-fir in the other hardwood forest type may be an indicator that regeneration is not the issue, but a lack of control of competing vegetation may be more relevant.

Relatively high probabilities of retention in and transition to Douglas-fir are common to both ownerships.

The forest type transition probabilities used in the projections differed by harvest type, but the patterns were similar between the two private owner groups (figs. 41 and 42). Although the general trend of relatively high probabilities of retention in and transition to Douglas-fir was common to both ownerships, the magnitudes of these changes did differ. For example, 78 percent of the forest industry Douglas-fir stands that were final harvested remained Douglas-fir, whereas 58 percent of the harvested Douglas-fir stands on NIPF timberlands remained as Douglas-fir.

The type transition matrices for final harvests used in the projections were calculated from USDA Forest Service Forest Inventory and Analysis (FIA) and American Forest and Paper Association (AF&PA 1999) data were similar in trends but differed in magnitudes (see app. 1). The major difference was that the AF&PA matrix showed higher levels of Douglas-fir retention, higher probabilities of stands transitioning to Douglas-fir after final harvests of other softwood or other hardwood stands, and lower transition rates to Douglas-fir following western hemlock–Sitka spruce or red alder final harvests.

Other Forest Cover Types in the Pacific Northwest West Subregion

Besides Douglas-fir, red alder was the most common (11 percent) forest type that Douglas-fir transitioned to in projections for forest industry timberlands, and other hardwood was the most common (21 percent) forest type that Douglas-fir transitioned to on NIPF timberlands.

Another example of ownership differences is that 5 percent of the red alder stands that were projected for final harvest remained as red alder, and 86 percent became Douglas-fir on forest industry timberlands. On NIPF timberlands, 39 percent of the red alder stands that were final harvested remained red alder, and 40 percent became Douglas-fir. This contributes to the projection of a reduction in hardwood area, especially on forest industry lands. Hardwood area on NIPF lands is also projected to decline, but the net loss masks some gains from other types (fig. 42). On NIPF timberlands, the other hardwood type area is projected to increase.

The projected decreases in the area of red alder on forest industry and NIPF lands are continuations of historical trends that have been influenced by relatively low market values for hardwood species such as red alder. Although the most current data do not reflect it, this trend may be changing because the market value of red alder is increasing. Although economic incentives for growing red alder are increasing, forest practice regulations encourage removal of some red alder (and other hardwoods) from riparian management areas and conversion of these riparian forests to conifer-dominated forest types to enhance aquatic habitats. Other projections largely follow historical trends, although the projected trends of the other hardwood forest type do depart from the historical trends.

Areas of most forest cover types in the Pacific Northwest East and Pacific Southwest are projected to decrease on private timberlands.

Forest Cover Projections for Other Subregions

For the Pacific Northwest East subregion, areas of most forest cover types on private timberlands are projected to decrease (figs. 39 and 40). Areas of the ponderosa pine and Douglas-fir/larch cover types, which cover about three-quarters of private timberlands, are projected to slowly decrease. Trends are consistent across both private ownership classes.

For the Pacific Southwest subregion, areas of most forest cover types on private timberlands are also projected to decrease (figs. 43 and 44). Exceptions are slight increases for the Douglas-fir and fir-spruce cover types. The trends are consistent across both private ownership classes, with one exception being the small increase in ponderosa pine area for forest industry.

Summary, Pacific Coast Region

In 1997, the most extensive forest covers on private land were Douglas-fir in the Pacific Northwest West subregion, Douglas-fir and ponderosa pine in the Pacific Northwest East subregion, and mixed conifers and hardwoods in the Pacific Southwest subregion. Douglas-fir is the major type in western Oregon and Washington, where it occupies about 60 percent of the forest area. Examples of other forest types that cover more than 10 million acres in a subregion are fir-spruce in Alaska and western hardwoods in the Pacific Southwest.

For the Pacific Coast region, the largest projected changes in the areas of forest types on private timberland are in the Pacific Northwest West subregion. This area experienced a large reduction in federal timber harvest in the 1990s because of increased protection for threatened and endangered wildlife species. This has shifted timber demand more to private timberland and other regions. Projected changes in forest cover areas include a decrease in the area of red alder and an increase in the area of Douglas-fir. The regional trends are dominated by the forest type dynamics of the forest industry because of their larger area of timberland. The changes are being spurred by the increased value of Douglas-fir. Conversely, hardwood area on this ownership is projected to decline. On NIPF timberlands, the largest projected changes are an increase in the area of other hardwood and decreases in the areas of Douglas-fir and red alder. Projected timberland losses on NIPF lands are distributed across all forest types. Projections include increases in other hardwood and other softwood types and decreases in the areas of red alder and western hemlock–Sitka spruce types.

For the Pacific Northwest East subregion, areas of most forest cover types on private timberlands are projected to decrease. Areas of the ponderosa pine and Douglas-fir–larch cover types, which cover about three-quarters of private timberlands, are projected to slowly decrease. The trends are consistent across both private ownership classes.

For the Pacific Southwest subregion, areas of most forest cover types on private timberlands are projected to decrease. Exceptions are slight increases for the Douglas-fir cover type and fir-spruce cover type.

Chapter 5: National Overview

Introduction

This chapter provides a national overview of the area projections for forest cover types. The endowment of 2.263 billion acres of land in the United States includes 33 percent (747 million acres) that is forest land. Forests are found in significant amounts in every region of the Nation. They range from sparse scrub forests of the arid, interior West to the highly productive forests of the Pacific Coast and the South, and from pure hardwood forests to multispecies mixtures and coniferous forests. About two-thirds (504 million acres) of the Nation's forests are classed as timberland, productive forests capable of producing 20 cubic feet per acre of industrial wood annually and not legally reserved from timber harvest (figs. 2 and 45). An additional 52 million acres of forest, reserved for nontimber uses, are managed by public agencies as parks or wilderness areas. Other forest lands on the remaining

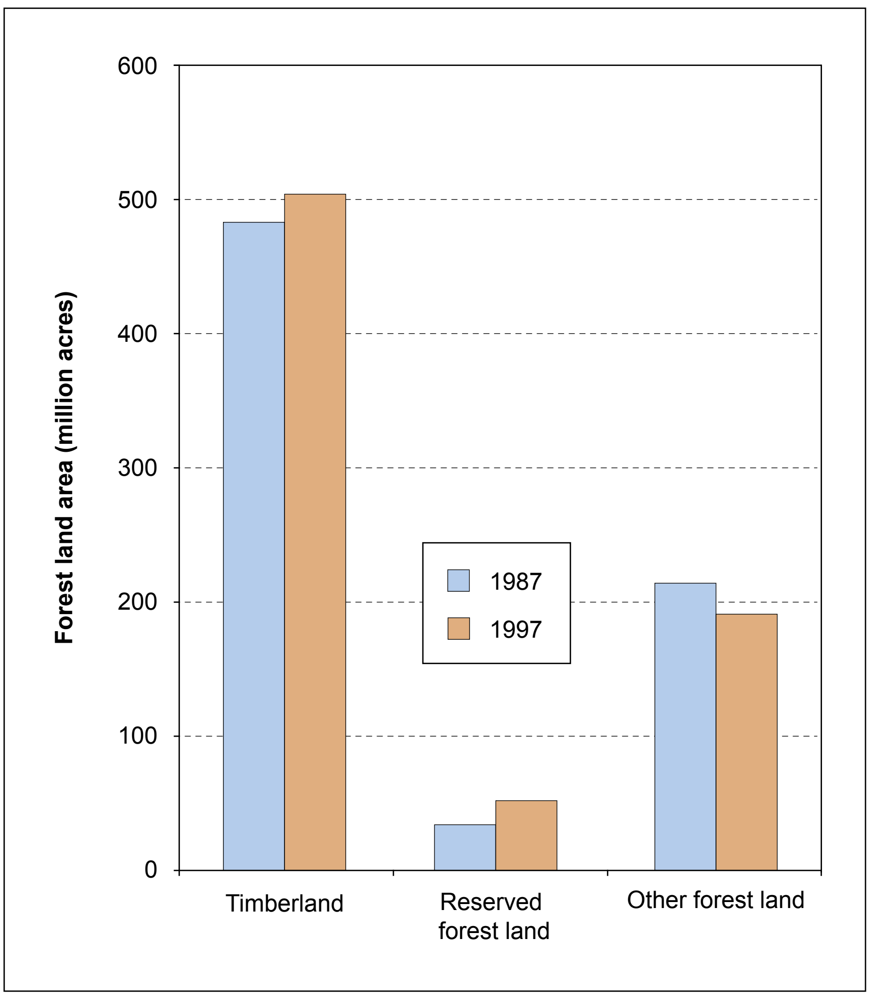


Figure 45—Composition of U.S. forest land by timberland, reserved for nontimber uses, and other forest land that has lower timber productivity (Smith et al. 2001).

U.S. softwood area on private timberland is projected to increase by 11 percent by 2050.

U.S. hardwood area on private timberland is projected to decrease by 8 percent by 2050.

191 million acres are not capable of producing 20 cubic feet per acre of industrial wood annually but are of major importance for watershed protection, wildlife habitat, domestic livestock grazing, and other uses and services. More than 90 percent of the "other" forests (see "Glossary" for definitions) are in the West, with more than half in Alaska.

Macro View of Forest Cover Projections

Projections of softwood and hardwood areas for the United States are shown in figure 46. Softwood area is projected to increase by 11 percent by 2050. Hardwood area drops by 8 percent, but in the East still dominates in both the North and South regions (fig. 47).

Table 4 lists the 12 largest amounts of projected regional area change for forest cover types. The largest projected changes in timberland area are for the South and North, the regions with the most existing timberland. The North is projected to have relatively small percentage changes in extensive types such as the maple-beech-birch type (less than 5 percent), whereas the South has larger percentage changes. This follows recent historical trends, as one of the largest changes in U.S. forest cover area over the last half century has involved pine cover types in the South. The South has the largest amount of relatively high productivity forest land in the United States (fig. 4), with many areas suitable for pine plantations. Area of planted pine in the South has increased more than tenfold since 1950, mostly on private lands (USDA Forest Service 1982, 1988, 2001). With respect to projections,

Table 4—The 12 largest projected changes in forest cover areas in the United States between 1997 and 2050 by subregion, private ownership group, and forest cover type

			Change	
Subregion	**Ownership group**	**Forest type**	**Area**	**Percentage**
			Million acres	
South Central	Nonindustrial private	Upland hardwood	-7.6	-19
South Central	Forest industry	Planted pine	5.7	81
South Central	Nonindustrial private	Planted pine	4.4	88
Southeast	Nonindustrial private	Natural pine	-3.4	-28
South Central	Forest industry	Upland hardwood	-2.5	-58
Northeast	Nonindustrial private	Elm-ash-red maple	2.4	101
Southeast	Nonindustrial private	Planted pine	2.3	29
Northeast	Nonindustrial private	Fir-spruce	-2.0	-49
Southeast	Forest industry	Planted pine	1.9	26
Great Plains	Nonindustrial private	Maple and beech	1.6	21
South Central	Nonindustrial private	Oak-pine	1.5	12
Lake States	Nonindustrial private	Aspen-birch	-1.5	-23

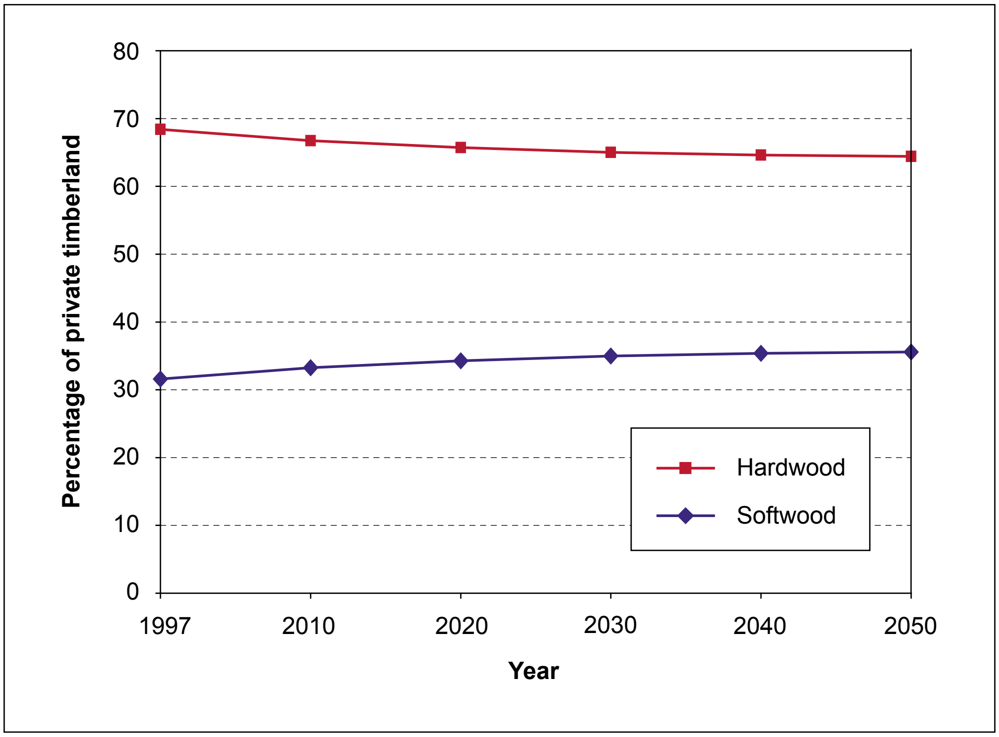


Figure 46—Projected percentages of softwood and hardwood type groupings on private timberlands in the United States.

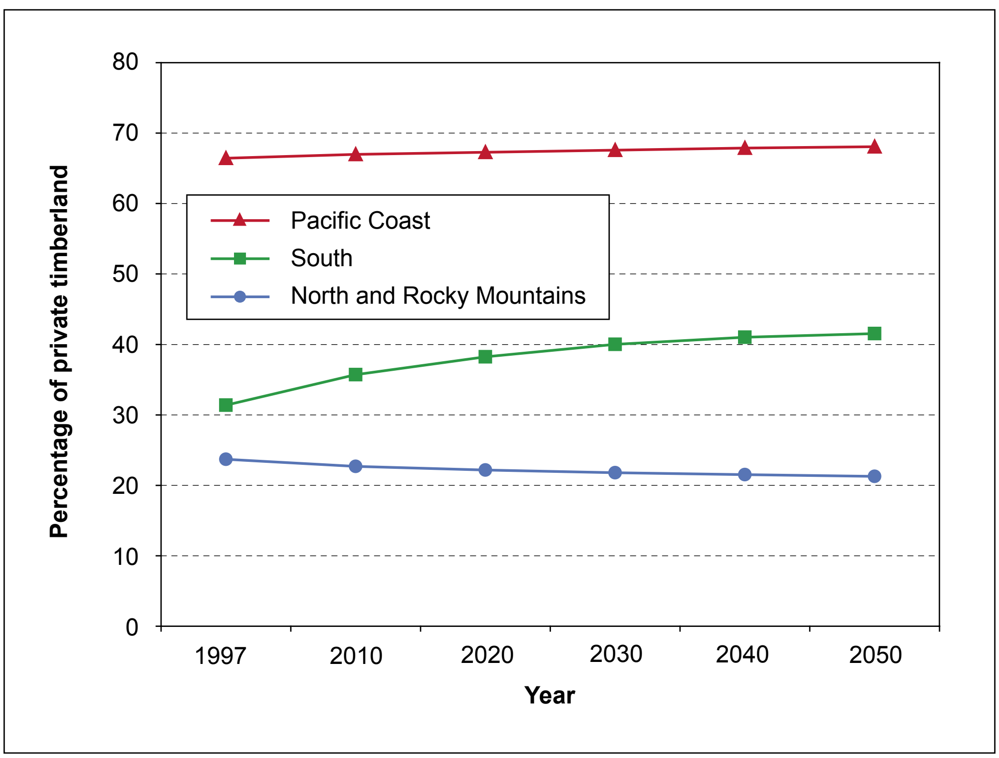


Figure 47—Projected percentage of private timberland in softwood forest type groupings by region, 1997 to 2050.

Although the U.S. area of softwoods is projected to increase across many regions, hardwoods will remain the dominant forest type on private lands.

The largest impact on forest cover dynamics in the United States has been from human influences, such as timber harvests.

the South also has relatively large changes: reductions of 19 percent for upland hardwood on nonindustrial private forest (NIPF) timberlands and 58 percent on forest industry timberlands in the South Central region; and increases in excess of 25 percent for planted pine on both private ownerships in the South. The increase in planted pine is the result of the assumed intensification of forestry practices in the South, a continuation of a current trend.

Although the area of softwoods is projected to increase across many regions of the country, especially on forest industry lands, hardwoods will remain the dominant forest type on private lands. One of the areas of largest change will be in the Southern United States. In particular, the relative areas of hardwoods and softwoods on forest industry lands are projected to increase from a nearly 1:1 ratio of softwoods to hardwoods in 1997 to a 3:1 ratio in 2050. On NIPF timberlands, the area of hardwoods is projected to remain dominant, but the 3:1 ratio of hardwoods to softwoods is projected to decrease to about a 2.5:1 ratio by 2050.

However, these net changes only tell part of the story. An examination of the gross changes shows a much more dynamic system. For example, the projected net increase of 14 million acres of planted pine in the South is the result of a gain of nearly 53 million acres of planted pine and a loss or reversion to other types of approximately 39 million acres out of planted pine.

Other major projected changes are an increase in the area of elm-ash-red maple forests in the Northeast and decreases in the areas of spruce-fir in the Northeast and aspen-birch in the Lake States. The increase in elm-ash-red maple is primarily due to the large influx of red maple in the region. The projected decrease in fir-spruce is related to the large areas infected by insect pests (e.g., spruce budworm) (*Choristoneura* spp.). The loss of aspen-birch has largely been the result of insufficient regeneration opportunities for this early successional forest type.

The largest impact on forest cover dynamics in the United States in the recent past has been human influences, especially changes in land management objectives. In the last half of the 20th century, application of intensive forestry has in some cases influenced the composition, structure, and ecological processes of forests. For example, plantations and clearcutting have replaced natural regeneration and selective harvesting on some sites in the United States. Intensive forestry on private timberland has generally reduced rotation lengths, which leads to more frequent regeneration opportunities and increases the probabilities of more forest cover changes. At the same time, a countervailing trend is seen in expansion of the number of forested acres acquired by private owners for purposes other than timber production. This growth in nontimber objectives and the incorporation of forest lands into residential ownerships has reduced the likelihood of some acres being intensively managed.

Another notable human-caused influence on forest cover area was government subsidized afforestation, principally, planted pine in the South (fig. 48). Cost-sharing for establishment has been important for NIPF owners (Alig et al. 1990b). Retention of subsidized plantations also has been relatively high (Alig et al. 1980, Kurtz et al. 1996).

Figure 48—Human-caused influences, including tree planting, timber harvests, and conversion of forests to developed uses, are a major factor in forest cover type changes in the United States,

Timber harvest is an important human-caused disturbance that has significant influences on forest composition and structure. Human disturbances result when people consciously or unconsciously alter the composition or structure of a forest. Timber management and land conversion are the most prevalent human disturbances in the forests of the United States. Natural disturbances include blowdowns from windstorms and hurricanes, lightning-induced fires, insect and disease outbreaks, and flooding. Many human disturbance events have large cumulative effects even if the individual disturbance events are localized. Some significant cumulative effects include the one-third reduction in U.S. forest cover since settlement by European Americans and fire suppression that has changed the dynamics of many ecosystems. Not all human-induced disturbances are localized; a notable exception is the chestnut blight that has eradicated chestnut trees (*Castanea dentata* Marsh. Borkh.) from eastern deciduous forests. The effects of natural disturbances span a broad range of spatial scales and generally are more episodic than human disturbance. The relative importance of disturbances differs by region. Human-caused disturbances are a function of ownership objectives and land rent, the latter being influenced by stumpage value, extraction costs, and distance to markets (Alig et al. 2003, Adams and Haynes 1996). Natural disturbances are a function of stand composition, stand structure, and distance to disturbance vectors.

Data from periodic forest surveys by the USDA Forest Service Forest Inventory and Analysis (FIA) units indicate a notable historical reduction in the area of nonstocked timberland from 1953 to 1997 (table 2, Smith et al. 2001). In general, nonstocked area was reduced in all regions between 1953 and 1997, with an overall national reduction of 85 percent. Some nonstocked areas are scheduled for reforestation, but at the time of the survey were not forested. Nonstocked area is about 1 percent of total national timberland area. The projections similarly show the nonstocked percentage to remain below historical levels.

Relationships Between Land Use and Land Cover Changes

From a national viewpoint, consideration of macrodemographic and socioeconomic forces helps one understand how areas in forest cover types are affected by exogenous factors such as population growth. Population growth is expected to continue and will lead to further deforestation. Deforestation is a part of forest type dynamics, which can be separated into forest-land gain (afforestation), forest-land loss (deforestation), disturbance, and succession processes. Gains of forest land occur when an area that was previously nonforested becomes forested, such as afforestation resulting in the conversion of an agricultural field to a conifer plantation. Given the possibility of two-way flows of land into and out of forestry, the specific pathways by which forest land is gained or lost in a locality will influence the characteristics of the residual forests. Losses of forest land occur when an area of land is converted from forest land to a nonforest-land use, such as a residential development.

Continued increases in urban and developed areas are projected at almost all state levels, mostly leading to reduced forest cover area.

The United States population is projected to increase by more than 120 million people over the next 50 years, and projections of population and general economic activity are the foundations for long-term analysis of the land use change and forest type changes (Alig et al. 2003, 2004). Within the macroeconomic outlook, the larger population will have larger incomes on average. Above-average population growth is projected for the South and West. In the South, projected conversion of forest land to developed uses involves millions of acres (Alig et al. 2003, Wear and Greis 2002), leading some to term it a major threat to forest sustainability. Per capita forest area in the United States is projected to decline from approximately 4.8 acres in 1997 to 1.8 acres in 2050. The corresponding decline for per capita timberland is from 1.8 to 1.2 acres.

Continued increases in urban and developed areas are projected for most states, mostly leading to reduced forest area. Table 5a shows examples from the Southern United States of exit transition probabilities of forest land by forest cover type for deforestation cases, and table 5b shows entry transition probabilities for afforestation cases. Transition probabilities by region were used as part of the national 2000 Forest and Rangeland Renewable Resources Planning Act (RPA) assessment. Projections to reflect forest type dynamics is the second of two phases

Table 5a—Proportions of timberland gains by forest type and ownership based on forest survey data for private timberlands in the Southern United States

Region and forest type	Forest industry	Miscellaneous corporate	Other private
Southeast:			
Planted pine	0.568	0.374	0.439
Natural pine	.229	.258	.230
Oak-pine	.012	.153	.096
Upland hardwood	.046	.134	.146
Lowland hardwood	.114	.069	.066
Nonstocked	.031	.012	.023
South Central:			
Planted pine	.243	.076	.092
Natural pine	.098	.065	.076
Oak-pine	.079	.077	.091
Upland hardwood	.355	.647	.656
Lowland hardwood	.210	.128	.080
Nonstocked	.015	.007	.005

Table 5b—Proportions of timberland losses by forest type and ownership based on forest survey data for private timberlands in the Southern United States

Region and forest type	Forest industry	Miscellaneous corporate	Other private
Southeast:			
Planted pine	0.255	0.172	.055
Natural pine	.157	.186	.177
Oak-pine	.149	.087	.142
Upland hardwood	.335	.501	.560
Lowland hardwood	.050	.021	.030
Nonstocked	.054	.034	.036
South Central:			
Planted pine	.185	.075	.044
Natural pine	.308	.204	.181
Oak-pine	.120	.107	.131
Upland hardwood	.260	.383	.503
Lowland hardwood	.127	.231	.138
Nonstocked	0	0	.003

Note: Within an ownership and forest type combination, the proportions should sum to one (within rounding error) down a column.

in a protocol to assess land use and land cover dynamics in the 10 regions and subregions recognized in the RPA assessment. The first phase of this makes area projections of forest and other land uses (Alig et al. 2003, 2004).

Links to Other Resource Planning Act Assessment Models

The methods used to project timber supplies in the RPA timber assessment (fig. 49) require assumptions relating to timberland area change, trends in future management investment, the efficiency of harvest utilization, and harvest flows from public timberlands. The 2000 RPA assessment assumes a continuation of recent government policies such as those related to forest resources, paper recycling, tree planting assistance, trade, or environmental protection. For example, we assume that no major tree planting programs will be funded over the projection period.

Harvests are a major factor in forest type transitions, and timber harvests from timberland within the national forests have decreased dramatically in the 1990s as the result of changes in the goals for federal land management. National forest timber harvests currently represent less than 10 percent of the U.S. timber supply (Smith et al. 2001). Under the base case assumption of continuation of current policies, national forest harvest is projected to continue at these lower levels for the next five decades (Mills and Zhou 2003), representing expectations based on current USDA Forest Service policy guidelines. Timber harvests are projected to rise slightly in some regions, reflecting actions to maintain forest health consistent with current regulations.

Given the assumption about federal timber harvests, private timber harvest is projected to supply about 90 percent of the Nation’s timber harvest. This includes some lowered timber harvest ages (Haynes 2003). In the 2000 RPA timber assessment, the supply of timber at any point in time is based on the contributions of four broad groups of timberland owners: national forest, other public, forest industry, and nonindustrial private. Timber available in any period from the public landowners is assumed to be set by agency direction. The two private ownerships—forest industry and nonindustrial private—are modeled as a function of the private timber inventory levels and stumpage prices (Adams and Haynes 1996). Private inventory levels and stumpage prices are both affected by the areas in different forest cover types.

In the past, technological changes have substantially influenced the yields for certain crops, including timber production, and also have affected the demand for certain products. Use of historical data reflects some trends in technological changes, whereas some technological changes cannot be foreseen. Changes in technology have been affecting the mix of softwood and hardwood fiber used by the pulp and

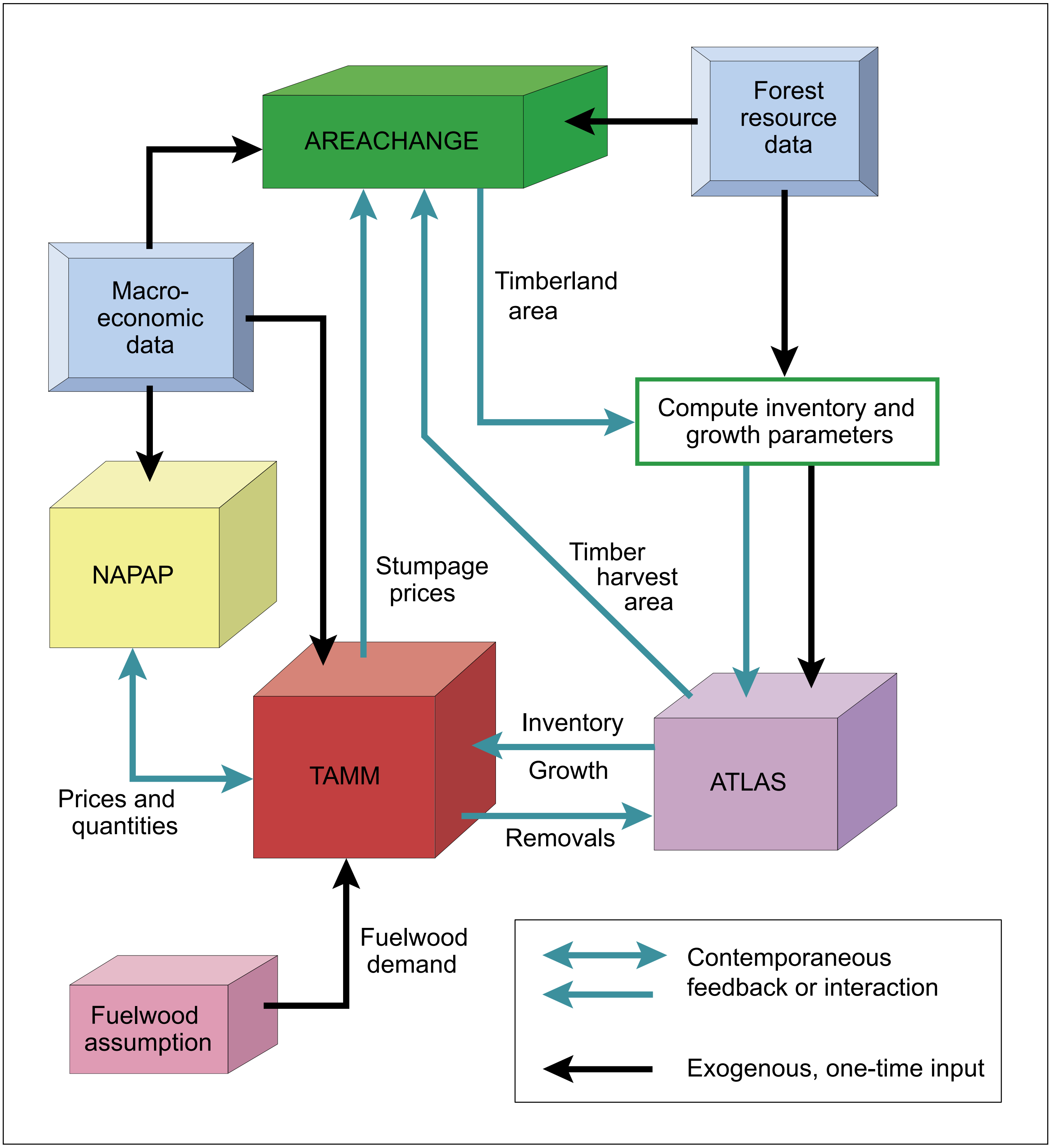


Figure 49—Bioeconomic system of models used in the 2001 RPA timber assessment (Haynes 2003).

paper industry (e.g., Ince 2000). One finding from the 2000 RPA timber assessment that represents a departure from the past is the increasing scarcity of hardwood timber supplies. To augment hardwood production from traditional timberlands, hardwood agrifiber supply—growing hardwoods such as hybrid poplars (*Populus* spp.) or cottonwoods (*Populus* spp.) on agricultural lands for fiber products—has been developed commercially on a limited scale in the United States.

About 0.1 to 0.2 million acres of agricultural land were planted in short-rotation woody crops in the 1990s (less than 0.1 percent of current U.S. cropland area). Hardwood agrifiber plantations on agricultural land have much higher potential productivity than natural hardwoods in forest stands, typically up to five or six times higher, but higher productivity comes at the expense of higher costs. The RPA base case analysis assumes that hardwood agrifiber supply has a potential to expand in the future if projected equilibrium prices for hardwood pulpwood are sustained at levels that are high enough to justify the higher costs of agrifiber supply (e.g., Alig et al. 2000a). Benefits from alternative use of the land in agriculture represent opportunity costs, but real prices for agricultural products are not projected to rise over the projection period (USDA Forest Service 2001). Another key assumption about short-rotation woody crops in the base case outlook is that there are no productivity or cost-saving improvements over the projection period.

Investigations of the possible influence of global climate change on forest cover areas are relatively recent. Our RPA projections embody whatever related influences are embedded in the historical time series of FIA data pertaining to forest cover types. Recent climatic changes have enhanced plant growth in northern mid and high latitudes (Irland et al. 2001). In large-scale simulations for a national climate change assessment, Alig et al. (2002a) projected an increase in net economic welfare, based partially on expanded forest area in the northern latitudes owing to global climate change as predicted by ecological models. To date, most earlier projections of climate change on forest cover area changes are relatively small compared to nearer term impacts from timber harvest, land use changes, and other human-caused factors. Changes in forest cover are also considered as policy options regarding mitigation activities (e.g., Alig and Butler, in press; Birdsey et al. 2001; Sohngen and Alig 2000). In particular, increases in planted pine are a focus of some policy deliberations.

More broadly, land use and land cover changes are part of global change, with feedbacks among land use, land cover, climate, and other parts of the biosphere (Alig 2003). As new findings accumulate, these can be used in scenario analyses to help place in perspective different sources of uncertainty and how they affect projected outcomes regarding future areas for forest cover types.

Sustainability Issues and Land-Based Policies

There is increasing interest in large-scale forest sustainability analyses and related aspects including changes in forest cover types. The 2000 RPA assessment is the first national-scale assessment in the United States to be organized around criteria for sustainable forest and rangeland management. These criteria include biological diversity; productive capacity of forest and rangeland ecosystems; forest and rangeland ecosystem health and vitality; forest contributions to global carbon cycles; socioeconomic benefits to meet the needs of societies; and the legal, institutional, and economic framework for forest and rangeland conservation and sustainable management. Forests are a critical natural resource of the United States, and the distribution of forest cover types is an indicator of the sustainability of the Nation's forests (Alig and Haynes 2002, United Nations Conference on Environment and Development 1993). Forests provide numerous amenities that foster the well-being of the Nation including raw materials for the paper and lumber industries, myriad habitats for a multiplicity of species, filtration systems to purify air and water, and recreational opportunities for countless individuals.

With the context of the latest RPA assessment broadening over earlier ones, this reflects increased interest in sustainable management of the world's forest resources, owing in part to the United Nations Conference on Environment and Development in 1992 (USDA Forest Service 2001). Since that time, various countries have joined together to discuss and attempt to reach consensus on ways to evaluate progress toward the management of their forest resources. The United States participates in the Montreal Process, designed to use a set of criteria and indicators for the conservation and sustainable management of temperate and boreal forests. The criteria provide a common framework for describing, assessing, and evaluating a country's progress toward sustainability at the national level.

Information from periodic RPA assessments, such as concerning forest cover trends, can help shape perceptions about whether we can sustain both increasing consumption of forest products and certain forest resource conditions.

Information from periodic RPA assessments can help shape perceptions about whether we can sustain both increasing consumption of forest products and forest resource conditions (Alig and Haynes 2002). Related data illustrate the dynamics of our Nation's land base and how adjustments are likely to continue in the future. The projections of land use and forest cover changes also provide inputs into a larger system of models that project timber resource conditions and harvests, wildlife habitat, and other natural resource conditions (USDA Forest Service 2001). Current debates about sustainability involve both physical notions of sustainability and competing socioeconomic goals for public and private land management. The land-base changes also indicate the importance of viewing "sustainability" across the entire land base and across sectors, in contrast to the current typical sector approach as in examining "sustainable forest management" (Alig and Haynes 2002). We do offer the periodic RPA assessments as a unique process that has monitored the forest resource situation and provided comprehensive analyses. Reassessments over time are necessary because of the dynamics on the land base, as well as changing social values. This is in contrast to "sustainability analyses" that propose to place the discussion of sustainability into a two-dimensional framework where the focus is on the status at a point in time as well as how indicators change over time.

Forest cover projections were one input used to examine broad-scale tradeoffs, compatible production, and the integrative nature of forest ecosystems.

The RPA forest cover projections were one input into an analysis by Haynes et al. (2001) that drew upon RPA timber assessment projections to provide broad-scale composite measures to look at tradeoffs, compatible production, and the integrative nature of forest ecosystems. They used total timberland area as one of the six indicators of a biophysical index, termed timberland integrity. Haynes et al. (2001) also used softwood percentage as another indicator, drawing upon forest cover projections. They proposed a timberland wealth measure in line with socioeconomic indicators, as a relatively parsimonious measure of the various economic and social criteria, i.e., a broad proxy for ecosystem wealth. Haynes et al. (2001) used total timber inventory in this measure, which is based in part on timberland area projections. Their results show that there has been a general decline in timberland integrity since 1952 but that the decline has slowed in the 1990s and is expected to stabilize in the future. In contrast, the timberland wealth measure has generally shown an upward trend since 1952 and is projected to increase in the future. Overall, the analysis by Haynes et al. (2001) suggests that the future outlook at a macroscale is one of stability or increases in timberland wealth, reflecting in part some forest area indicators.

These results show that there has been a general decline in many of the indicators characterizing conservation of biological diversity (criterion 1) and maintenance of productive capacity (criterion 2) but that this decline has slowed in the 1990s and is expected to stabilize in the future. At the same time, measures of socioeconomic benefits (criterion 6) have shown increases, suggesting that whereas in the period 1950–89 there were tradeoffs between ecological conditions and economic benefits, changes in public attitudes, improving forest management, and increased productivity of forest lands resulted in greater balance by the 1990s. For example, from a timber supply perspective, increases in growing-stock inventories have offset fragmentation and parcelization and have slowed the shift from softwoods to hardwoods. In terms of magnitude of change, some of the greatest changes took place between 1976 and 1986 and involved increased harvests, especially of hardwoods for pulpwood and fuelwood.

The results also show an apparent contradiction. That is, what causes inventory to keep increasing when growth is about equal to or less than harvest? The answer lies in the proportion of the volume less than 5 inches in diameter that is not included in the reported volume of inventory (Smith et al. 2001), which includes the increasing area of relatively fast-growing plantations, as for the planted pine type in the South. Periods when the proportion of southern softwood inventory less than 5 inches is relatively high include this decade and the 2030 decade. Not apparent in these national summaries are regional differences. For example, much of the increase in inventories and proportion of softwoods comes in western softwood species whereas most of the increase in harvest comes from southern pines, especially from pine plantations.

The various series also suggest that we are seeing an aging of the forests as more timber harvest is obtained from planted acres and less from naturally regenerated forests. Overall, most timber types remain relatively stable after some initial declines in the 1950s and 1960s. The results also show that although fragmentation has emerged as a natural resource issue (e.g., Alig et al. 2000b; Butler et al., in press), it is not expected to escalate as an issue in proportion to the amount of area harvested. That is not to say that its importance will diminish as a land use issue, with perhaps more important impacts for wildlife habitat in some cases. United States timber consumption continues to increase as a function of population growth but per capita consumption falls slightly.

These results have positive implications for the contribution of U.S. forests to global carbon cycles (criterion 5). In general, U.S. forest management has resulted in increasing total levels of carbon storage (Birdsey et al. 2001), and forest inventory levels are projected to increase by 42 percent over the next 50 years (Haynes 2003). Projected changes in forest inventories on timberland are the net result of increments from growth and reductions owing to timber harvests, and net changes in the forest land base. For the United States as a whole, total softwood inventories are projected to increase about 53 percent by 2050. This increase reflects the recent declines in harvests and stable growth on public timberlands, growth in excess of harvest on private timberlands, and slowing conversions of private forest land to other uses. An important part of the softwood inventory growth is from young, rapidly growing southern pine and Douglas-fir plantations. The U.S. hardwood inventory is projected to increase in volume by 28 percent by 2050. Although overall hardwood growth is relatively stable, a major expansion in inventories in the North will offset a decline in the South (Haynes 2003).

As a key driver in forest type transitions on private lands, the volume of U.S. timber harvest has risen by 67 percent since 1952.

It is important that future discussions about "sustainability" and any policy actions be viewed within the context of existing resource conditions, supplies, and demands and with some expectation of future trends. Haynes et al. (2001) argue that the sustainability debate will progress when the debate shifts away from two-dimensional arguments about the environment-versus-jobs tradeoffs to one that addresses strategic questions about the compatibility of wood production with ecological and socioeconomic goals. The efforts by Haynes et al. (2001) drawing upon the RPA timber assessment represent one source of information on the status and trends of renewable forest and rangeland resources in the United States; however, they do not explicitly consider sustainability options and issues in other sectors, such as agriculture or energy. Another caveat is that although there are a number of criteria and indicators identified in the Montreal Process, not all of these indicators can be currently addressed owing to lack of available data. Some information was available for most indicators, but data were completely lacking for others. In many cases, data that were available had been collected only in recent years, making it impossible to determine trends, or data had not been measured in all locations by using consistent definitions or methodologies. These data problems made it inappropriate or impossible to draw conclusions.

With respect to timber production sustainability, the RPA timber assessment indicated that the U.S. forest sector has the potential to sustain current timber harvest amounts at the national level, with stable to declining softwood log prices in the long term (Haynes 2003). Private timberlands have the biological potential to provide larger quantities of timber on a sustainable basis than they do today, but additional investments in tree planting and timber management intensification would be required.

As a key driver in forest type transitions on private lands, the volume of U.S. timber harvest since 1952 has risen by nearly 67 percent. This has been accompanied by growing timber inventories on both public and private lands (Haynes 2003). In recent years, the United States has consumed nearly 18 billion cubic feet per year of newly harvested roundwood of all types and from all geographic sources. For softwoods, 85 percent comes from domestic harvests. The United States has been a modest net exporter of hardwood.

With the United States relying significantly on softwood lumber imports, trade issues can affect areas of forest cover types in the country. Approximately 17 billion board feet of softwood lumber were imported from Canada in 1997. Harvest restrictions in Canada were put in place in some areas of coastal and interior British Columbia in the early 1990s (Canadian Forest Service 1999). Future timber harvests in Canada may be limited by allowable timber harvest limits and may be further influenced by softwood lumber trade agreements between the United States and Canada.

Looking at future harvests, we link our modeling of forest cover changes to other modeling in the 2001 RPA timber assessment (Haynes 2003). Most of the U.S. timber harvest (80 percent in 1997) takes place in the East. Most of the expected increase in harvest will come from managed stands, primarily in the South. By 2050, about 60 percent of the softwood timber harvest from private timberlands will come from plantations, both in the South and Pacific Northwest West subregion, which occupy about 30 percent of the softwood timberland area and less than 20 percent of the total timberland area.

The plantation area is expected to increase most in the South, which overall has about 10 times as much private timberland as the Pacific Northwest. Demand for pulpwood is important, as use of softwood pulpwood from southern pine plantations is expected to increase. With lumber and plywood composing a decreasing share of total forest products output, virtually all of the projected increase in U.S. timber harvest is in nonsawtimber trees—trees used for oriented strand board or paper and paperboard. The overall share of timber harvest from nonsawtimber will increase from 44 percent in 2000 to 66 percent by 2050. For the most part, age structure of forests will shift toward a greater proportion of acres in sawtimber with the exception of decreasing sawtimber acres for private hardwood timberland in the South and for private softwood timberland in the West, although in the West, the sawtimber proportion will increase after 2020. The use of recycled paper more than doubled between 1978 to 1993, along with increasing demand for paper products. Along with other timber supply and demand factors, recycling can contribute to changes in timber prices and can affect demand for pine plantations and other forest investments.

United States forests will continue to change in structure and composition; while species composition of U.S. forests will shift toward softwoods in the South, hardwoods will continue to dominate the regional landscape.

United States forests will continue to change in structure and composition, most strikingly in terms of expanded pine plantation area in the South, increased age and density of forests on public lands (primarily in the West), and increased timber harvests in the South. Planted pine area in the South will increase by about 40 percent by 2050. This is tied in part to the increased timber harvests in the South, which provide increased opportunities for reforestation after harvest. Expansion of the planted pine area will result in more timber from planted sources, allowing more naturally regenerated forests to be used in other ways. Some of these include public timberland, which on average will grow older and more dense. For example, area of timberland with trees older than 150 years in the National Forest System is expected to more than double by 2050.

In contrast to pine plantations, hardwood forest types in the South have lower rates of growth, less intensive forms of timber management, and expected declines in the area available for timber production (Haynes 2003). The knowledge of intensive hardwood silviculture is not as well developed as for softwoods, and silvicultural activities in hardwood stands are complex owing to the relative diversity of trees and forest species. In addition, many hardwood forests are in small ownership parcels, held in many cases by NIPF owners with various land management objectives. The overall area of hardwood forests in the South is projected to decline 7 percent through conversion to other forest types (predominantly softwoods), losses to urban and developed uses, and reservations for nontimber purposes. These projections suggest a future in which recent concerns about the broad-scale consequences of increasing timber production from Southern hardwood forests, such as loss of understory plants, noncommercial tree species, and wildlife habitat (e.g., Flather et al. 1999), will continue or intensify (Haynes 2003).

Summary, National Overview

Key findings from the 2001 RPA timber assessment include that human impacts are responsible for many of the changing land conditions, in part owing to increasing population and increased demand for wood products. Loss of forest cover is due primarily to population expansion. From 1982 to 1997, more than one-third of the land converted to urban or developed uses was forested. Consumption of forest products in the United States will increase over the next 50 years but at a slower rate than in the past, rising 40 percent by 2050. More U.S. wood is being grown than is harvested, a trend that is expected to continue even as wood production and consumption increase substantially in the United States (Haynes 2003).

The growing importance of nontimber forest goods and services, such as water, is increasing as human population increases, and forest cover often plays a critical role in providing such goods and services.

Over the next 50 years, most of the increase in the Nation's timber harvest is projected in the East, and especially on NIPF timberlands in the South (Haynes 2003). Plantations of softwood species will play an important role in future domestic timber harvest expansion. With this, the species composition of U.S. forests will shift toward softwoods in the South; however, hardwoods will continue to dominate the regional landscape, but related ecosystems may face increasing pressure because of land use conversions, timber production, and other disturbances. Species composition will move more toward hardwoods in the North and will remain largely unchanged in other regions. The changes in species composition are not large, as measured in terms of the percentage of total timberland area in each region. Diversity indices that combine information on both age and forest types exhibit limited change over the projection period (1997 to 2050) for the United States as a whole (Haynes 2003).

Land cover change is a widespread and significant process. In many cases, it is driven by human actions, and in many cases it also affects humans. United States trends are part of worldwide trends toward more timber production from managed forests, including more plantations, so that timely broad-scale reassessments and up-to-date data are important for effective policy analysis. In addition, the importance of nontimber forest goods and services, such as water, is increasing as population increases, and forests often play a critical role in providing those goods and services.

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Metric Equivalents

When you know:	Multiply by:	To get:
Feet	0.3048	Meters
Cubic feet	.0283	Cubic meters
Acres	.4047	Hectares

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Appendix 1: Forest Cover Database and Forest Cover Area Studies

We document the major forest cover database that we drew from for this study. "Land use" and "land cover" are sometimes used interchangeably, but the two terms are not the same. Land use is the purpose to which land is put by humans, e.g., protected areas, forestry for timber products, plantations, row-crop agriculture, pastures, or human settlements. Land cover is the observed (bio)physical cover on the Earth's surface (Di Gregorio and Jansen 1998), e.g., oak-hickory forest. This report pertains to land cover, whereas Alig et al. (2003) document land use changes involving U.S. forests.

Data Sources

Forest cover data are collected by various agencies for a variety of purposes and from various sources, including remotely sensed data and that from ground-based inventories. Our need was for a set of forest cover data that were consistent nationwide with respect to statistical data-collection methods, scope, and a variety of other characteristics, e.g., linkage to timberland and ownerships classifications. Thus, we drew upon the Forest Inventory and Analysis (FIA) data assembled to support the 2000 Forest and Rangeland Renewable Resources Planning Act (RPA) assessment by the USDA Forest Service (e.g., Smith et al. 2001).

The FIA surveys conducted by the USDA Forest Service are designed to provide objective and scientifically credible information on key forest attributes, such as forest stocks, growth, harvest, and mortality. Related data are collected on region, forest ownership category (e.g., forest industry vs. nonindustrial private forests [NIPF]), and cover type (e.g., oak-hickory), by using a sample of more than 70,000 permanent plots. The FIA inventories provide consistent forest inventory data for the Nation back to 1953 (Smith et al. 2001). Originally, FIA had established a fixed grid of points across the United States, with the intention of remeasuring forest attributes on these plots every 5 to 15 years. Since the 2000 RPA assessment work, FIA has moved to an annual inventory system. The FIA inventories measure approximately one field plot for every 6,000 acres of forest land in most regions.

The FIA inventories in conjunction with the RPA assessments have now resulted in four related databases: (a) East-wide; (b) West-wide standard forest inventory databases; (c) national timber products output database, and (d) a national summary database that draws upon the others and also incorporates other data from the U.S. Bureau of the Census (total land area, population, etc.). The FIA inventory data are gathered by using photointerpretation and ground truthing on a systematic sample of plots defined as pinpoints on the ground. These data include land use and ownership characteristics of sample plots, among other data, providing consistent and complete coverage for all private timberlands. Inventories by FIA were used for a description of initial conditions and use in projections because a systematic approach and consistency are prime concerns.

Forest cover types in FIA surveys are classified based on the forest species forming a plurality of the live-tree stocking (Smith et al. 2001). A forest type group is a combination of forest cover types that share closely associated forest species or site requirements and are generally combined for brevity of reporting. An example is the white-red-jack pine cover type group, comprising forests in which eastern white pine (*Pinus strobus* L.), red pine (*Pinus resinosa* Ait.), or jack pine (*Pinus banksiana* Lamb.), singly or in combination, compose a plurality of the stocking. Common associates include hemlock (*Tsuga* spp.), aspen (*Populus* spp., and maple (*Acer* spp.). Forest cover types identified in the FIA surveys are classified according to 22 types used in this study, with 10 in the East and 12 in the West.

One supplementary source of data was timber resource data for industry lands from a survey conducted by the American Forest and Paper Association (AF&PA 1999). The numbers compiled by the AF&PA include forest area owned in a aregion by member firms and were used to calculate a final harvest probability matrix. We weighted AF&PA and FIA-based final harvest matrices so that a heavier weight was given to the AF&PA inputs because their values reflect future intentions, whereas the FIA values reflect past behaviors. We had AF&PA inputs for three major timber supply regions and used these weights for the AF&PA matrix for forest industry lands in the respective regions: South—0.75, Lake States subregion—0.60, and Pacific Northwest West side subregion—0.75.

Another supplementary source of data was final harvest matrix data for NIPF timberlands in the South, from a survey of state forestry agencies (Moffat et al. 1998). We weighted the state forestry agency and FIA-based final harvest matrices equally, so that for the South, the weight was 0.5 for each source. Similar surveys were not available for other regions; in those cases, the FIA weight is 1.

Methods Used to Project Area Changes in Forest Cover Types

Empirical methods used to project area changes for forest cover types on private timberland differ by region of the United States. Methods differ depending on the likelihood that area changes affect forests, the likely policy relevance of forest area changes, and the availability of data, especially time series of forest cover type data with which to develop models of forest cover change. Next, we first summarize the general approach, and then we provide more details on the approach used for the South that had relatively longer time series of comprehensive data on forest cover types.

The analysis of forest cover dynamics was conducted by categorizing timberland by region, ownership, forest cover, and disturbance categories at two points in time. The regions are those used by the RPA assessment (fig. 1).

Area changes for forest types on a particular ownership can result from four basic sets of activities: afforestation, deforestation, shifts among forest cover types on retained timberland, and ownership exchanges. In contrast to ecological processes, land use changes and disturbances can differ significantly by type of private ownership. Ownership changes in the timberland base may result in new owners with different land management objectives or different access to types of technology or available resources to invest in forest management. Changes in the areas of forest types often reflect differences in land management objectives among owners and indicate the differential influence of natural and human-caused management forces.

We modeled forest type transitions based on empirical analysis of data from remeasured FIA survey plots. Data pertaining to ownership, forest cover, land use, and forest productivity from the two most recent surveys in each state were used to calculate the forest type area vectors and forest type transition matrices (e.g., Alig and Wyant 1985).

Projections of such area changes for major forest types take into account the likelihood of timber harvest and forest successional forces (Alig and Wyant 1985). Forest type transitions for an aggregate grouping of timberland (by a stratum representing a specific region and ownership) are conditional on three disturbance types—no harvest, final or clearcut harvest, and partial harvests. Within the system of RPA models (fig. 49), projected harvest information is provided by the overall TAMM/NAPAP/ATLAS/AREACHANGE modeling system (e.g., Adams and Haynes 1996, Alig et al. 2002b) from the 2000 RPA timber assessment (Haynes 2003).

Forest cover projections are made with Markov chain models (Alig and Wyant 1985), which use timber harvest probabilities from the TAMM/NAPAP/ATLAS portion of the modeling system for harvest disturbances. Harvest estimates lead to adjustments in timber inventories (and broad-scale vegetation conditions) given changes in forest growth and timberland loss and gain. The volume of available timber inventory is then fed back to both the solid wood and paper and board models as a major determinant of stumpage supply. For other disturbance categories (e.g., windthrow), primary data sources were USDA Forest Service's FIA periodic forest surveys, AF&PA (1999) survey data, and a survey of state foresters regarding NIPF timber management tendencies documented by Moffat et al. (1998).

Changes in area among forest cover types affect both the nature and volume of timber available from forests. For example, decreases in timber production can occur when commercial species are replaced by noncommercial species. Area change projections by forest management type were based on assumptions about the probability that a particular acre will receive a certain type of management or disturbance and the associated probabilities that an acre so managed will remain in the same forest type or will make the transition to other forest types (fig. 50).

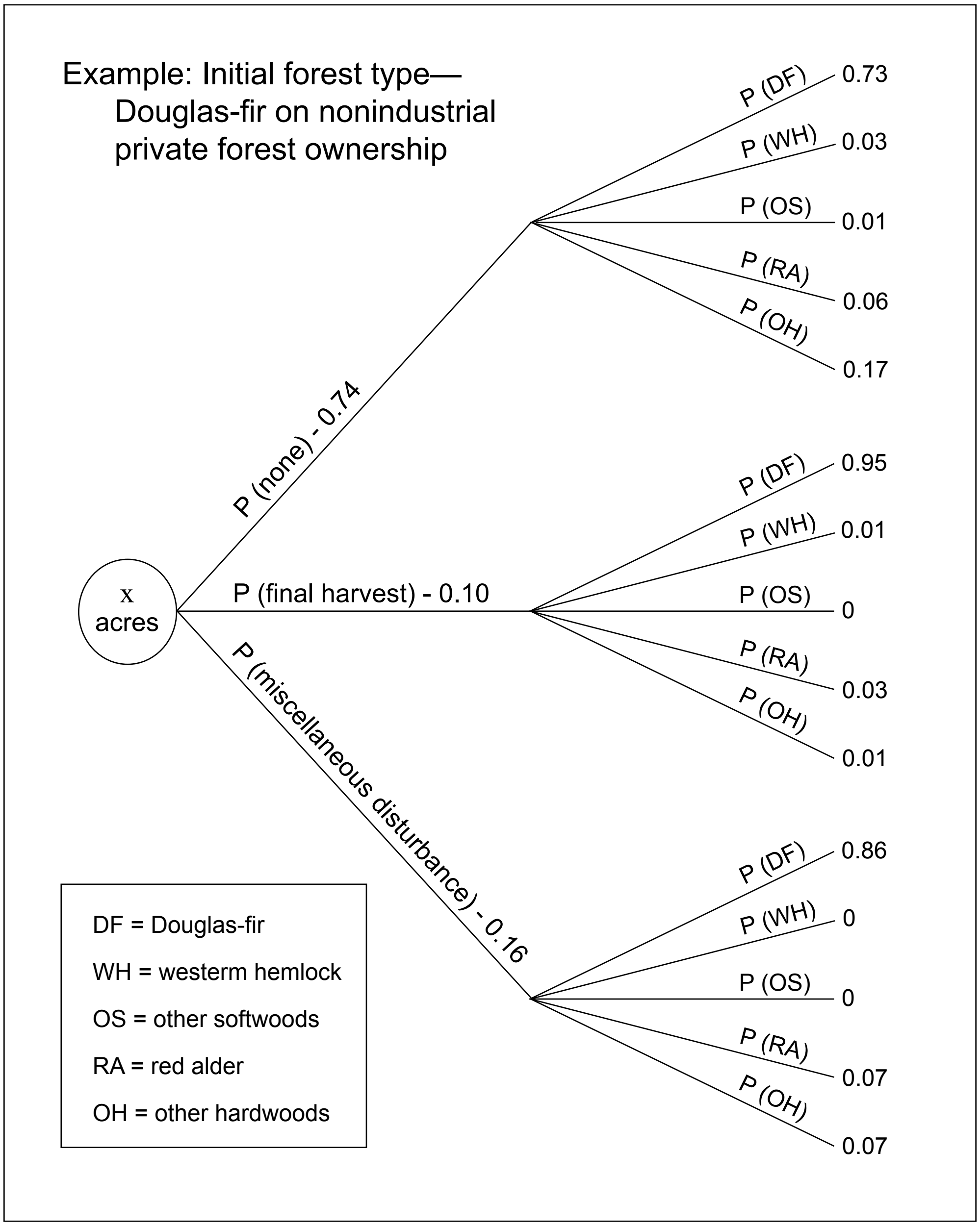

Figure 50—Example of probability tree for forest type transitions on nonindustrial private forest timberlands in the Pacific Northwest West subregion (Alig et al. 2000c).

Final harvest, partial harvest, and no harvest are the disturbance categories. A final harvest is the removal of trees from a stand that results in a residual stand that is not manageable for timber production. Final harvests include clearcuts, shelterwoods, and seed tree silvicultural treatments. A partial harvest is a human activity that removes timber from a stand but leaves enough trees to allow management of the residual stand for timber production.

Forest cover dynamics also can be influenced, in part, by other humans. Human-caused disturbances typically occur more frequently than natural ones on private timberlands, sometimes with a frequency that is an order of magnitude higher (e.g., Alig 1985, Alig et al. 2000c). Afforestation, such as the conversion of an agricultural field to a conifer plantation, is one important example. Deforestation, when land is converted from forest land to nonforest (e.g., a residential development), is another example of human-caused disturbances that can have significant influences on forest composition. Human-caused disturbances can interact with natural disturbances (e.g., insects) and also can set back successional trends. Successional processes involving recruitment, growth, reproduction, and mortality are involved in determining inter- and intraspecies competition and forest stand dynamics.

Example: Projection Model for the South Region

Area changes for forest cover type changes in the South have been some of the more important ones between 1953 and 1997. The South had less than 3 million acres of planted pine before 1950, and since then more than 25 million acres of pine plantations have been established on previously nonforested lands or converted from other forest types (Alig et al. 2002b).

Given the importance of the region for forest industry, supplementary data were obtained from a forest industry survey. The AF&PA (1999) conducted a survey of future forest management intentions of forest industry landowners. These survey data were used to construct a final harvest transition matrix of forest covers for forest industry timberlands, described below. For NIPF timberlands, state forestry agencies in the South were surveyed to provide supplementary data (Moffat et al. 1998).

Other inputs to the southern modeling were exogenous land use projections (Alig et al. 2003) and exogenous harvest probabilities (Haynes 2003). Land use changes involving afforestation and deforestation affect areas of forest cover types over time (fig. 51). Deforestation is most often caused by conversion to other land uses. This contrasts to timber harvests as part of typical forestry activities, because timber harvests are often followed by regeneration back to forest (Alig 1985). The land use projections of timberland area by region and ownership through 2050 were

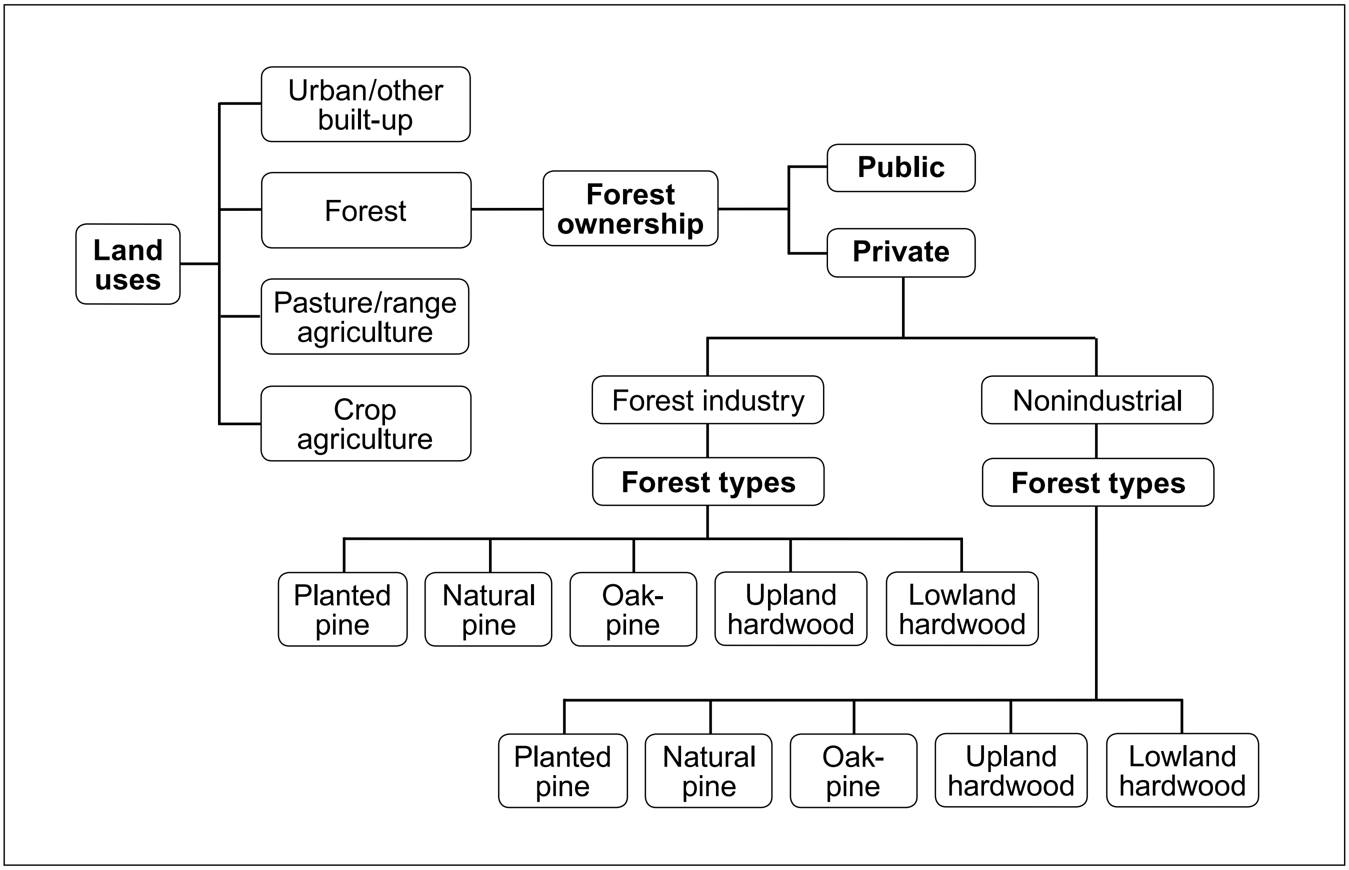

Figure 51—Designation of land uses and relations of overall land use modeling to that for cover types with the modeling system for RPA assessments, with example of forest cover types for the South region.

based on econometric analyses (e.g., Ahn et al. 2001). Harvest probabilities were calculated through an iterative process involving the TAMM/NAPAP/ATLAS/AREACHANGE modeling system (fig. 49) (Haynes 2003).

Forest cover dynamics were modeled by using a series of forest cover transition matrices and disturbance probability vectors (equations 1A and 1B). These three forest cover transition matrices and four probability vectors represent the major processes affecting forest composition and are a refinement of the Markov chain method developed by Alig (1985). Each of the matrices and vectors were calculated from FIA data, unless otherwise noted, and were calculated separately for each region and ownership group.

$$F_t = (hF'_{t-1})P_H + (pF'_{t-1})P_p + (F'_{t-1} - pF'_{t-1} - hF'_{t-1})P_N \, . \qquad (1A)$$

$$F'_{t-1} = (\tau_t - \tau_{t-1})D + F_{t-1} \quad \text{(area adjustment)} \, . \qquad (1B)$$

where

F_t = a vector of forest cover areas at time t,

F'_{t-1} = a vector of forest cover areas at time t–1 adjusted for timberland gains or losses,

τ = the area of timberland at time t or t–1,

D = an afforestation vector if $\Delta\tau > 0$ or a deforestation vector if $\Delta\tau < 0$,

h = final harvest probability vector,

p = partial harvest probability vector,

P_H = forest cover transition matrix following a final harvest,

P_p = forest cover transition matrix following a partial harvest, and

P_N = forest cover transition matrix for nonharvested lands.

The harvest probability vectors can be interpreted as the probability of a final or partial harvest occurring within a given forest cover. The final harvest probability vector (*h*) is the proportion of a given ownership's forest cover area in which all merchantable trees will be harvested in a given period. The partial harvest probability vector (*p*) is the proportion of a given ownership's forest cover area that will be partially harvested in a given period. The final harvest and partial harvest vectors were calculated by dividing the area of the forest cover that was final harvested or partially harvested by the total area of the forest cover. All probabilities are based on the average remeasurement periods.

The afforestation and deforestation vectors were calculated by dividing the area of a given forest cover that was either gained or lost by the total area of timberland that was gained or lost. The afforestation vector describes the allocation of forest covers among timberland that is gained from nontimberland land uses. The deforestation vector describes the allocation of forest covers among timberland that is lost to nontimberland land uses.

A forest cover transition matrix is a state/fate matrix that represents the probability of a given forest cover (state) remaining the same or becoming a different forest cover (fate) in a subsequent period. To calculate these matrices, the areas of each state/fate combination were first calculated with the state forest covers as rows and the fate forest covers as columns. For example, an element of an area matrix might represent the area of upland hardwood (state or row) that was converted to planted pine (fate or column) following a final timber harvest on NIPF lands in the Southeast. These area matrices were converted into probability matrices by dividing each element by the row/state total, i.e., the total area of that forest cover in the earlier period.

The forest cover transition matrices for nonharvested timberlands (P_N) are state/fate matrices with elements that are the probabilities that a given forest cover will remain in the same forest cover or transition into a different forest cover owing to succession, natural disturbance, and nonharvest human disturbance processes. The forest cover transition matrices for final harvested timberlands (P_H) are state/fate matrices with elements that are the probabilities that a given forest cover will remain in the same forest cover or transition into a different forest cover following a final harvest. The forest cover transition matrices for partially harvested timberlands (P_p) are state/fate matrices with elements that are the probabilities that a given forest cover will remain in the same forest cover or transition into a different forest cover following a partial harvest.

The initial forest cover areas were calculated from FIA data. The acreages were calculated by multiplying the forest cover proportions by the total timberland area. The allocation (proportion) of forest covers was extracted from the FIA database (http://ncrs2.fs.fed.us/4801/fiadb/index.htm) by dividing the area of each forest cover by the summed area of all forest covers from the most recent forest inventories. The total timberland areas were extracted from the RPA data tables (Smith et al. 2001).

The harvest probabilities taken from projections by the TAMM/NAPAP/ATLAS/AREACHANGE modeling system become part of the vector *h* in equation [1B]. This approach is similar to that used in the South's Fourth Forest study (USDA Forest Service 1988).

Given the importance of timber harvests in forest type transitions, feedback loops in our projections included incorporating disturbance probabilities and market price signals from the set of national timber supply models that projects timber prices (fig. 52) (e.g., Adams and Haynes 1996). We adjusted projections of planted pine area at certain time steps if subsequent projections for Southern timber prices were significantly higher than those used in the original model run. We drew upon recent elasticity estimates from the tree planting study by Kline et al. (2002), which give the percentage of change in planted pine area for a corresponding percentage of change in Southern timber prices. The response is inelastic in that the change in planted pine area is less than the corresponding percentage of change in Southern timber prices. This is true partly because private owners may alter use of other nonland inputs (e.g., fertilizer) in response to timber price changes.

An example of feedbacks involving timber prices is the case of pulpwood prices in the South. Pulpwood prices are influenced by the RPA projection of an increased supply of softwood pulpwood-size material in the South after 2010. The net effect is a softwood price drop after 2010, which thereby somewhat dampens incentives

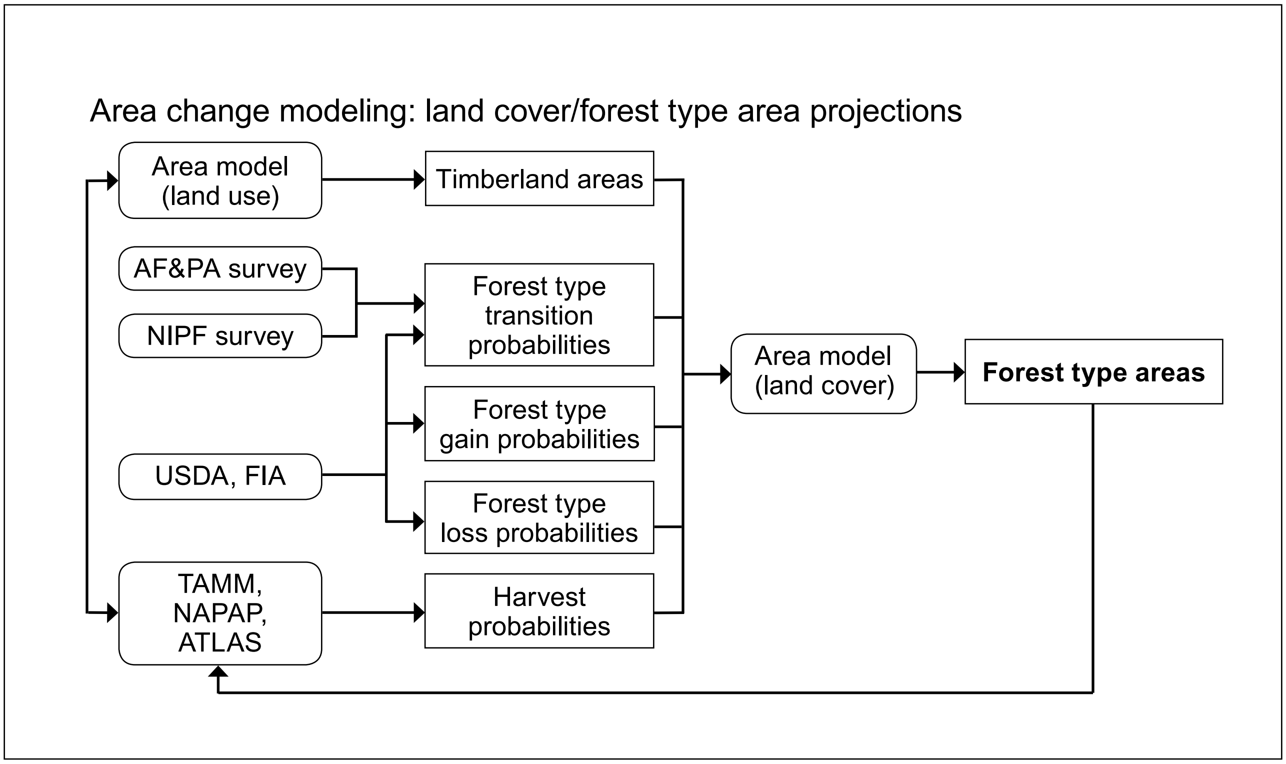

Figure 52—Flow chart for use of major input sets in the modeling system for projecting forest cover type areas in national assessments.

for establishing more pine plantations. This contributes to smaller future additions to pine plantation area compared to the first several decades (fig. 52). Lower price projections in the later decades make pine plantations financially less attractive, so less agricultural land and area of other forest types is converted to plantations. In those decades, projected expansion in pine plantation area would outpace projected changes in timber demand, and timber prices would drop.

The RPA model system captures interregional effects of price changes as well as price feedbacks each period. The South Central subregion is the likely location of any future increases in timberland because of net gains from land exchanges with agriculture (e.g., Ahn et al. 2002), whereas future reductions in timberland area would be concentrated in the Atlantic Coast States. The South Central subregion has more than twice the land area of the Southeast and more potential for expansion in pine plantation area. More than two-thirds of the future addition to plantation area is projected to be in the South Central subregion. Actual future outcomes are likely to be sensitive to relative economic returns for forestry versus agriculture in the region, which will be influenced by the timber price projections described above.

Future Modeling Research

As with all modeling and projection endeavors, our work has identified possible improvements as more data accumulate and techniques evolve. One research need is to investigate nonstationarity. That is, a major assumption involving the Markov method used in this study is that the probability matrices and vectors do not vary over time (i.e., it is assumed that the same driving forces that produced the observed probabilities will remain constant throughout the projection period) with the exception that the harvest probabilities varied in line with projections by the TAMM/NAPAP/ATLAS modeling system. The structure of the model can be adapted to handle other nonstationary vectors and matrices, but we did not have satisfactory methods for estimating these values.

Another research need is to increasingly integrate land use and forest cover models, including consideration of forest investment. For example, in the South Central subregion used in this study, we tied to land use projections by Ahn et al. (2002). A key interface is the afforestation pathway, especially for planted pine in the South. More fully integrated models would aid in policy deliberations pertaining to mitigation activities for climate change concerns (Alig 2003). Expanded data pertaining to forest cover on nontimberland forest land and public forest land would also aid in climate change analyses, including compiling time series of data.

Area trends for forest cover types also differ by major forest ownership class, and additional research can aid in identifying likely future changes. An example is that about 70 percent of timberland owned by timber investment management organizations in the South is planted pine, much higher than the overall percentage for the broader NIPF ownership class. A survey indicated that such institutional investors plan additional conversions of other forest types to pine plantations (Siry and Cubbage 2002); however, there is significant variation among such investors concerning type of forest management. Although total timberland holdings by such organizations was relatively small in 2000, less than 5 percent of total timberland, some suggest a strong growth potential (Siry and Cubbage 2002). Behavior by such owners is important as well for a broad array of forest-based goods and services, as these owners pursue a mixture of financial and conservation goals.

Other research needs include more information on the implications of high-grading harvests on forest cover over time. A variety of timber harvest methods are used across the United States and can affect the species mix under some regeneration activities. Harvests on private timberland also are influenced at times by owners' responses to institutional elements, such as partial harvesting that satisfies reforestation regulations without requiring substantial investment in active regeneration. Such responses need to be monitored, along with any significant shifts in forest covers.

Appendix 2: Species Diversity by Region

South

Diversity and composition of trees differed widely among forest types, although a few species, such as loblolly pine (*Pinus taeda* L.) and sweetgum (*Liquidambar styraciflua* L.), were observed in all forest types (figs. 53–58). The species diversities (i.e., number of species) within each forest type were fairly constant across ownerships, but the relative species abundances varied significantly. For example, loblolly pine was the dominant species in the planted pine forest type across both private ownerships, but it accounted for 90 percent of the volume on forest industry timberlands, 79 percent on miscellaneous corporate timberlands,[1] and 78 percent on other private timberlands in the Southeast subregion.

Other important species in the planted pine forest type were slash (*P. elliottii* Engelm.) and longleaf (*P. palustris* P. Mill) pines. The natural pine forest type also was dominated by loblolly pine with 67 percent of the forest industry, 55 percent of the miscellaneous corporate, and 59 percent of the other private timberland volumes in the Southeast subregion being accounted for by this species. Longleaf, pond (*P. serotina* Michx.), and shortleaf (*P. echinata* P. Mill.) pines were other important species in the natural pine forest type. The oak-pine forest type was dominated by loblolly pine, oaks (*Quercus* spp.), sweetgum, swamp tupelo (*Nyssa sylvatica* var. biflora (Walt.) Sarg.), and spruce pine (*P. glabra* Walt.). The upland hardwood forest type was dominated by oaks (especially white oak [*Quercus alba* L.]), sweetgum, yellow-poplar (*Liriodendron tulipifera* L.), and hickories (*Carya* spp.). The lowland hardwood forest type was dominated by swamp tupelo, red maple (*Acer rubrum* L.), sweetgum, yellow-poplar, oaks, baldcypress (*Taxodium distichum* (L.) Rich.), and ash (*Fraxinus* spp.).

Pacific Coast

The western hemlock–Sitka spruce forest type was dominated by western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) on forest industry timberlands and was codominated by western hemlock and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) on NIPF private timberlands. Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and red alder (*Alnus rubra* Bong.) were other important species in the hemlock-spruce forest type. Western redcedar (*Thuja plicata* Donn ex. D. Don) was the most common species in the other softwood forest type, but this forest type contained a

[1] Additional Forest Inventory and Analysis data allow the nonindustrial private forest ownership class to be separated into miscellaneous corporate and other private classes (see "Glossary") in the South.

diversity of species including Douglas-fir, western hemlock, Pacific silver fir (*Abies amabilis* Dougl. ex. Forbes), grand fir (*A. grandis* (Dougl. ex D. Don) Lindl.), bigleaf maple (*Acer macrophyllum* Pursh), and red alder. Red alder was the dominant species of the red alder forest type with Douglas-fir, western redcedar, and bigleaf maple as important subdominants. The other hardwood forest type contained a large diversity of species including Douglas-fir, bigleaf maple, red alder, and Pacific madrone (*Arbutus menziesii* Pursh). Other hardwood and other softwood types were the most diverse cover types, and Douglas-fir was the least diverse (figs. 59 and 60).

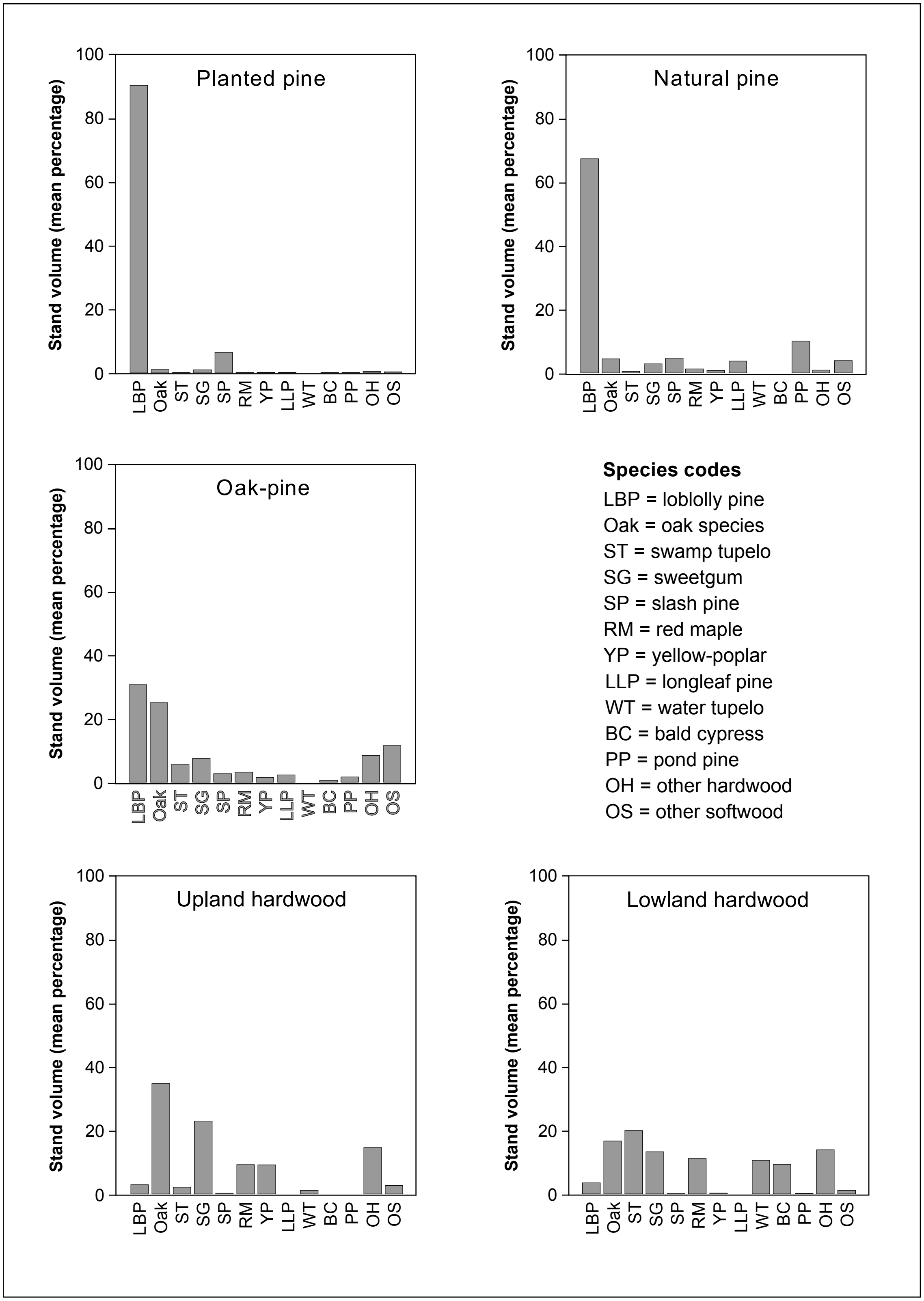

Figure 53—Species diversity in the Southeast subregion, forest industry timberlands, 1997.

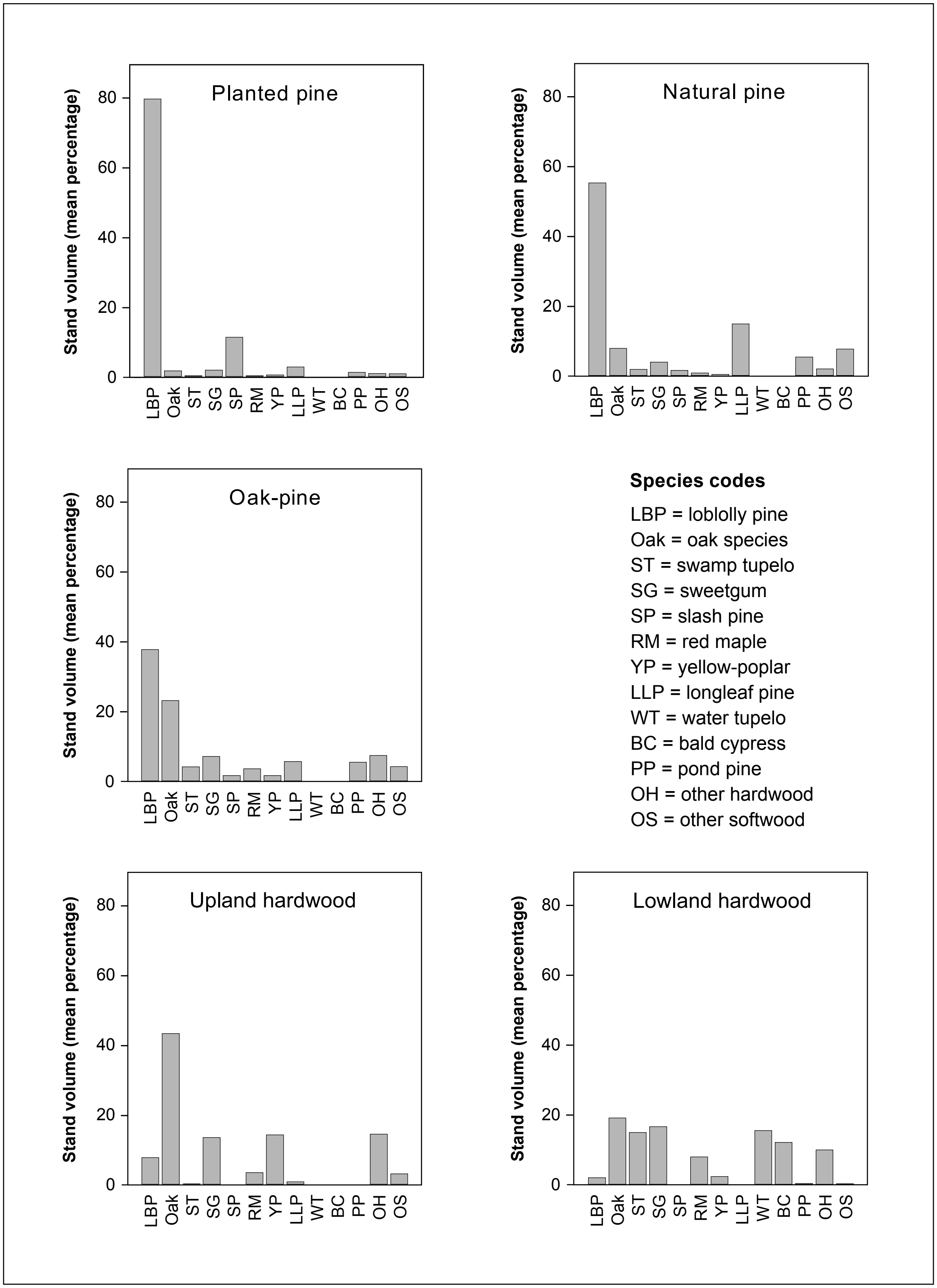

Figure 54—Species diversity in the Southeast subregion, miscellaneous corporate timberlands, 1997.

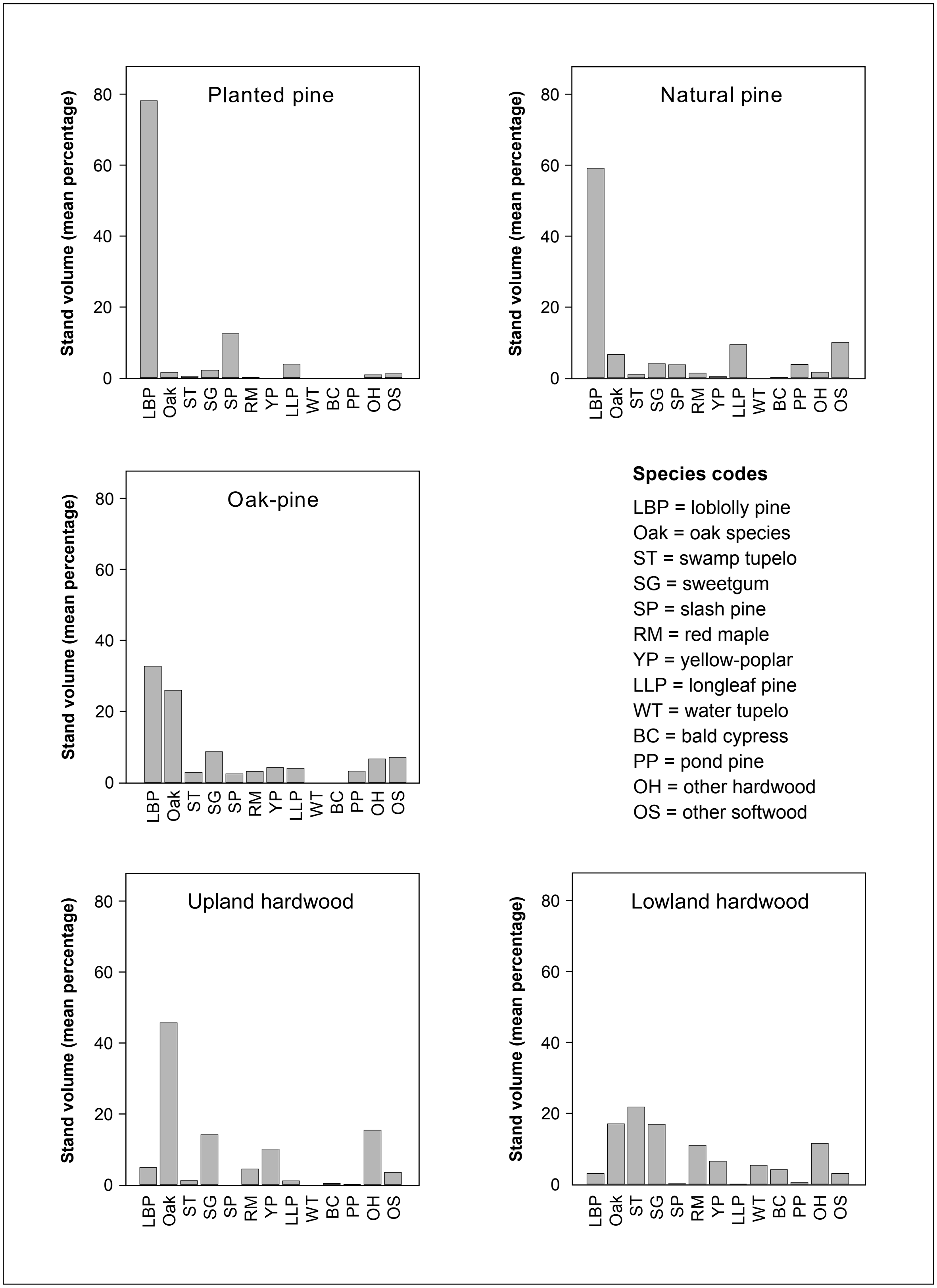

Figure 55—Species diversity in the Southeast subregion, other private timberlands, 1997.

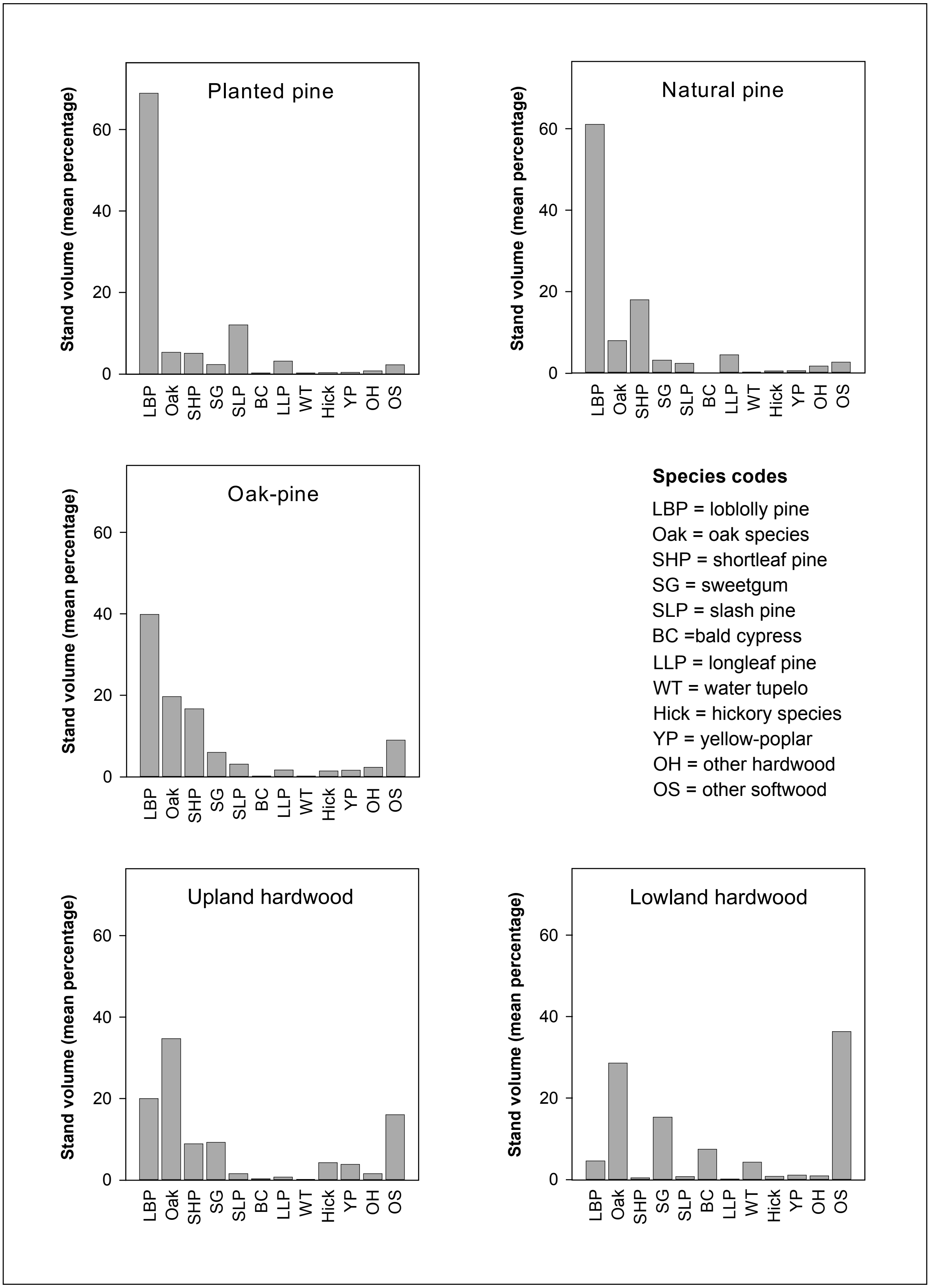

Figure 56—Species diversity in the South Central subregion, forest industry timberlands, 1997.

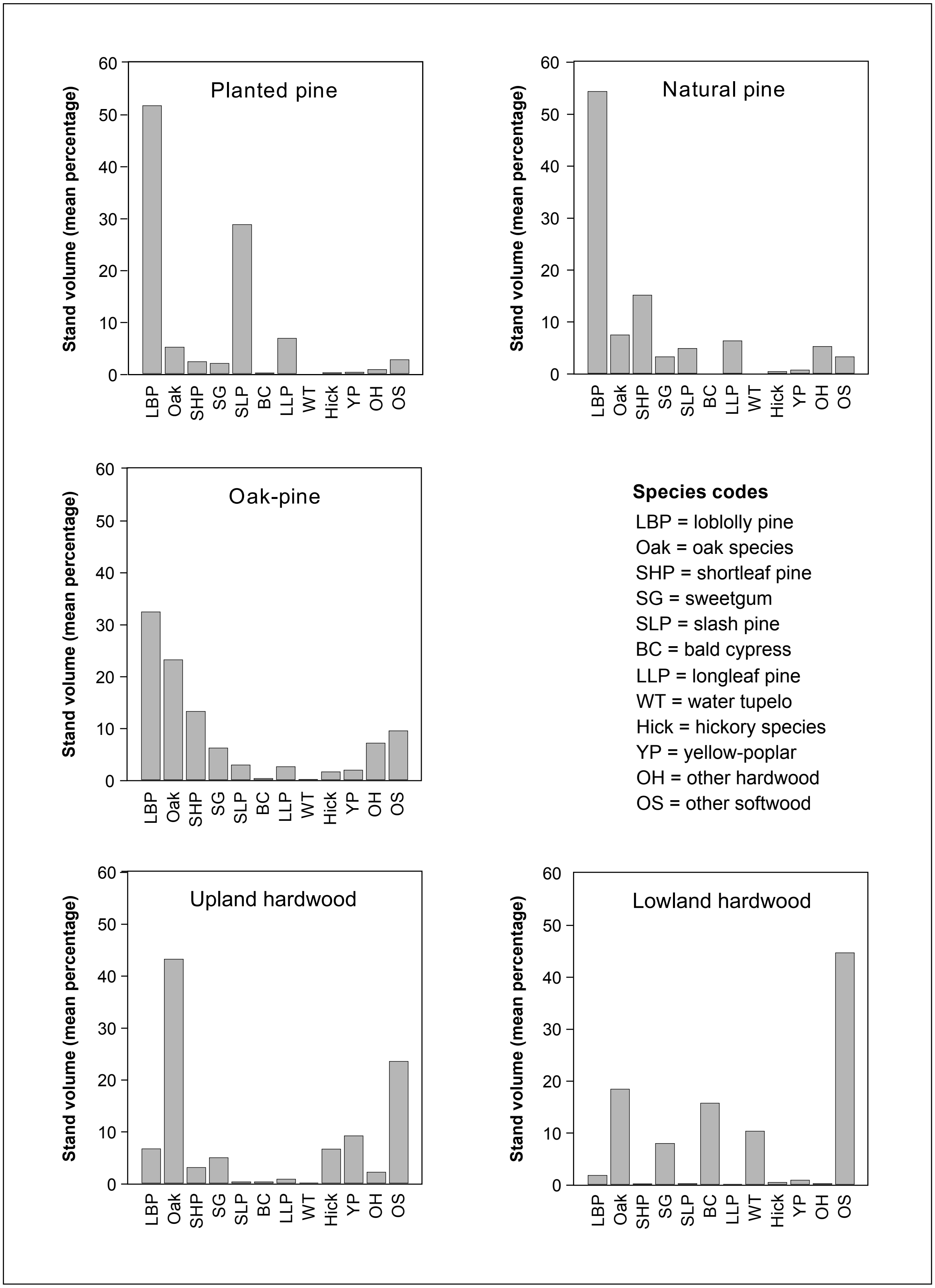

Figure 57—Species diversity in the South Central subregion, miscellaneous corporate timberlands, 1997.

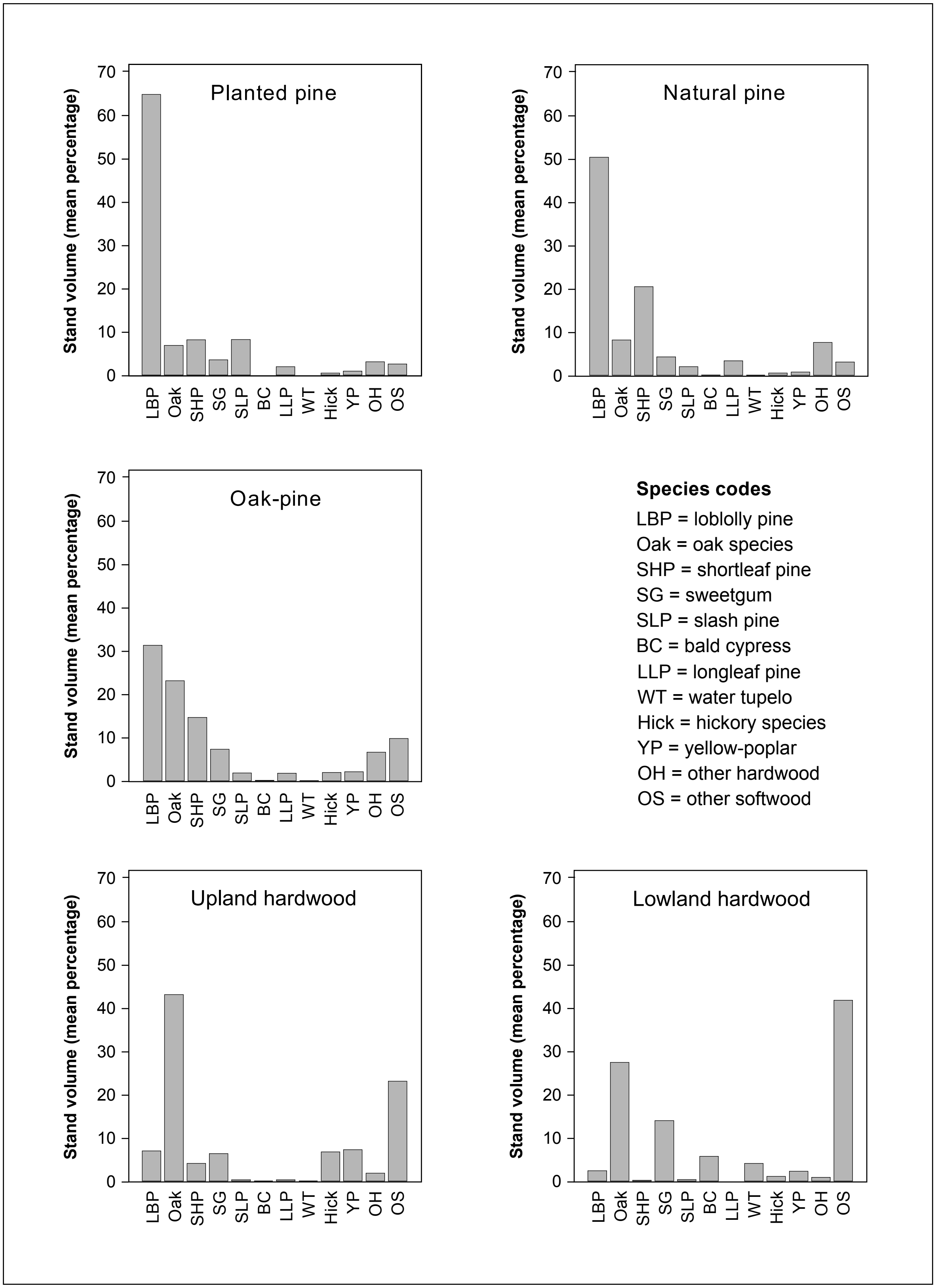

Figure 58—Species diversity in the South Central subregion, other private timberlands, 1997.

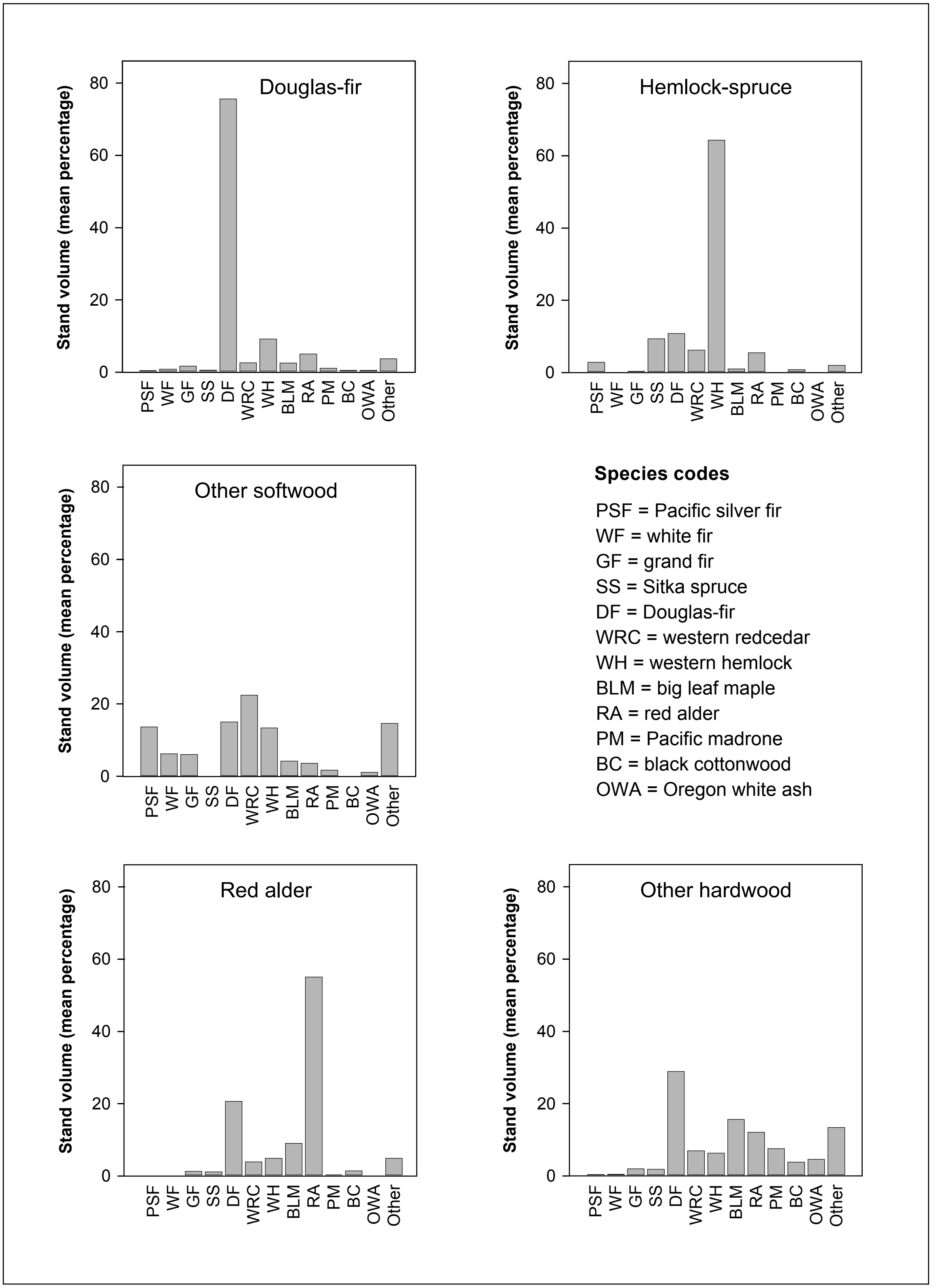

Figure 59—Species diversity in the Pacific Northwest West subregion, forest industry, 1997.

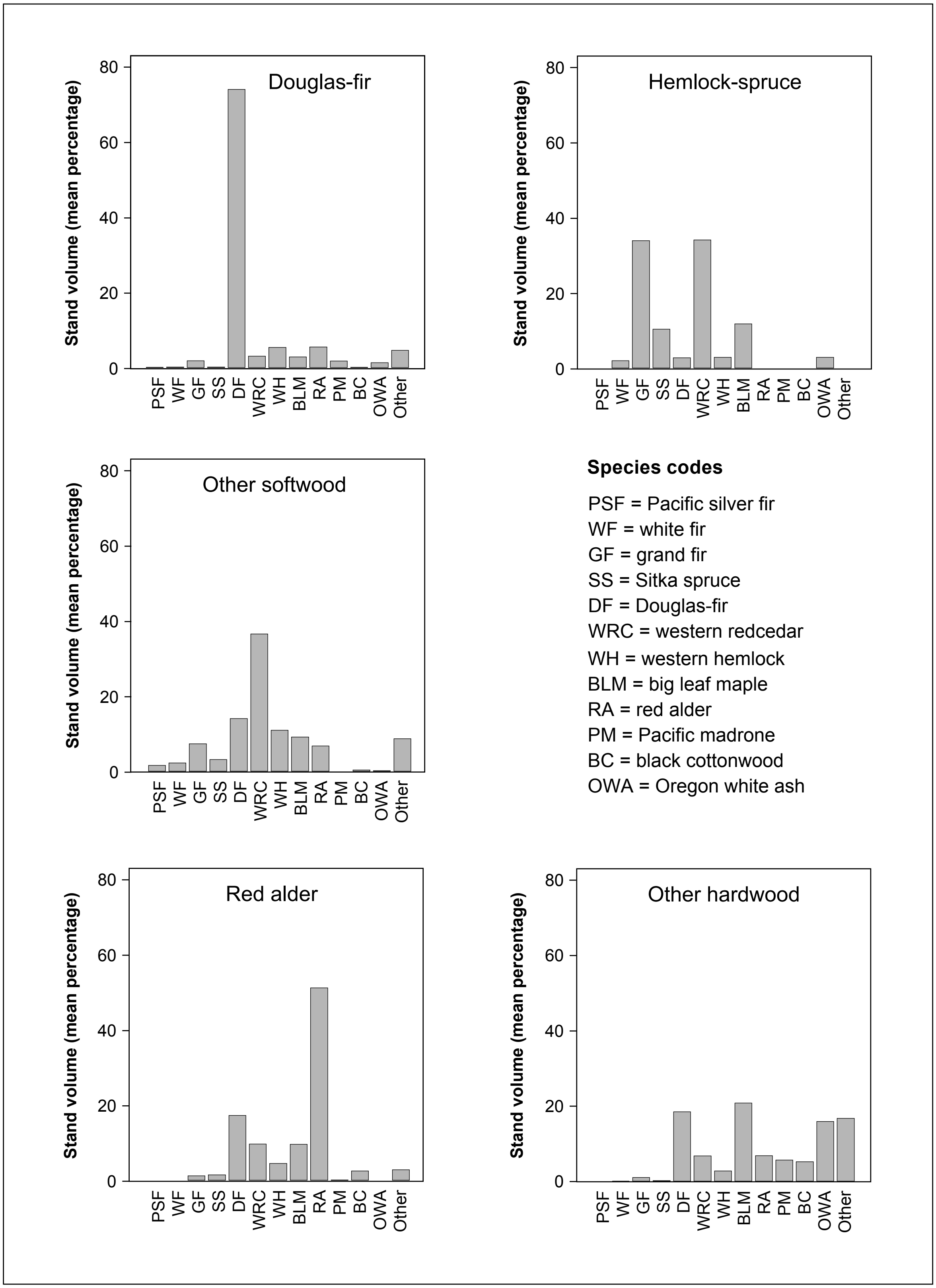

Figure 60—Species diversity in the Pacific Northwest West subregion, nonindustrial private forest timberland, 1997.

Glossary

Afforestation—The forestation, either by human or natural forces, of nonforest land.

Forest cover type—A classification of forest land based on the species presently forming a plurality of the live-tree stocking.

Forest cover type group—A combination of forest cover types that share closely associated species or site requirements and are generally combined for brevity of reporting (e.g., white-red-jack pine).

Forest industry—An ownership class of private lands owned by companies or individuals operating wood-using plants.

Forest Inventory and Analysis—Regional USDA Forest Service research units that assess forest conditions and trends on forest land and timberland.

Forest land—Land at least 10-percent stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10-percent stocked with forest trees and forest areas adjacent to urban and built-up areas. The minimum area for classification of forest land is 1 acre. Roadside, streamside, and shelterbelt strips of timber must have a crown width of at least 120 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide.

Forest-use land—A "major land use class" of the USDA Economic Research Service. This class differs from forest land in that it excludes forested land that is classified as "special uses" land, e.g., federal and state parks, wilderness areas, and wildlife refuges.

Land area—The area of dry land and land temporarily or partly covered by water, such as marshes, swamps, and river flood plains; streams, sloughs, estuaries, and canals less than 200 feet wide; and lakes, reservoirs, and ponds less than 4.5 acres in area.

Miscellaneous corporate—Timberland privately owned by corporations other than forest industries and incorporated farms; they are part of the nonindustrial private forest ownership class.

Nonindustrial private forest—An ownership class of private lands where the owner does not operate commercial wood-using plants.

Public—An ownership class, comprising land owned by federal, state, county, or municipal governments.

Reserved forest land—Forest land withdrawn from timber utilization through statute, administrative regulation, or designation.

Timberland—Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. (Note: Areas qualifying as timberland are capable of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included).

Urban and built-up areas—These areas consist of residential, industrial, commercial, and institutional land; construction and public administrative sites; railroad yards, cemeteries, airports, golf courses, sanitary landfills, sewage plants, water control structures, small parks, and transportation facilities within urban areas.

Pacific Northwest Research Station

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