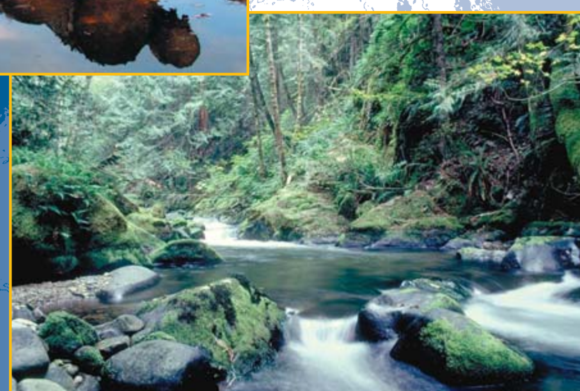
Projecting National Forest Inventories for the 2000 RPA Timber Assessment

John R. Mills and Xiaoping Zhou



A Technical Document Supporting the 2000 USDA Forest Service RPA Assessment

U.S. Department of Agriculture Forest Service

Authors

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Abstract

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National forest inventories were projected in a study that was part of the 2000 USDA Forest Service Resource Planning Act (RPA) timber assessment. This paper includes an overview of the status and structure of timber inventory of the National Forest System and presents 50-year projections under several scenarios. To examine a range of possible outcomes, results are shown for five removals scenarios that incorporate assumptions from both current and past studies of wood flows and harvesting on national forests. In addition, two projections were developed to examine the effects of volume reductions associated with large-scale disturbance events, such as fires, insects, and disease. Projections were made by region and forest type by using the aggregated timberland assessment system and plot-level inventory data with methods consistent with procedures followed for private timberlands in the assessment. The results of projected inventory volume differ across regions, but the total inventory of both softwood and hardwood forest types is shown to increase in all scenarios. One result is a shift in area to older age classes. Initially, 15 percent of the timberland is classified as stands older than 150 years; under the base scenario with disturbance, this area will increase to 32 percent by 2050. This shift means that in the future, a larger share of U.S. timberland is projected to support mature and old forest conditions.

Keywords: National forests, timber supply, modeling, inventory projection, yield function, seral stage, public policy.

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Introduction

The USDA Forest Service conducts periodic assessments of the condition of all forest and rangeland resources in the Unites States under the authority of the Forest Rangeland Renewable Resource Planning Act of 1974 (RPA 1974). The structure of these periodic assessments allows for the synthesis and integration of the current state of scientific knowledge and supports the development of mathematical models to project resources into the future. The 2000 RPA timber assessment is part of this broader study, which includes all resources such as water, minerals, wildlife, and recreation. The purpose of the timber assessment is to report the current status of the resources, survey the prospective changes in the land and timber resource base, estimate the major determinants of trends in demand and supply, and examine the implications of these trends in making 50-year projections of the U.S. forest sector. The results presented here document projections made for national forest timberland as part of this assessment.

National forests (fig. 1) support some 147 million acres of forest land, or about 20 percent of the 747 million acres of forested land in the United States (Smith et al. 2001). Approximately two-thirds of national forest area is classified as timberland,[1] whereas 19 percent is in a class known as reserved[2] forest land. The remaining 15 percent of forest land is less productive in the capacity to grow wood, but is not reserved from harvest. The timber volume, or growing-stock inventory, on national forest timberland amounts to 30 percent of the U.S. total. Figure 2 illustrates the timberland area and volume distribution among all four U.S. ownership groups: National Forest System (NFS), other public, forest industry, and nonindustrial private forest (NIPF) owners. Among these owners, the national forests are unique in that 77 percent of NFS timberland is in the mountainous regions of the West where 96 percent of the inventory volume is found in species of trees considered softwoods. Overall, 88 percent of NFS timberland inventory is softwood volume, whereas softwood fiber makes up about two-thirds of the forest industry inventory. The other public inventory is just over half softwood volume. The largest timberland owner class, NIPF, is located in the Eastern United States (89 percent) and is roughly two-thirds hardwood inventory volume. Many NFS lands are located in terrain that is difficult to access and are governed with policies aimed at producing a variety of public goods and only moderate levels of removals.[3] Many acres of NFS timberland have never been accessed with roads and the timber never harvested, creating the situation where NFS has, overall, a greater proportion of older trees than do forests in other ownerships. Today, the NFS mandate continues to differ from the other ownerships as it focuses on a broad spectrum of outputs and issues surrounding the management of publicly owned forested ecosystems.

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[1] Land capable of producing at least 20 cubic feet of industrial wood per acre per year and not withdrawn from timber production.
[2] Forested land under administrative or legal statute withdrawn from timber use.
[3] The terms "harvest" and "removals" are often used as if they are interchangeable, but technically, they mean different things. Inventory is presented in units of net growing stock, it represents sound merchantable tree volume, and the term "removals" specifically refers to the amount of this net growing-stock volume removed by cutting trees. Removals volume is subtracted from the net inventory. In a technical sense, harvest volume describes what wood is available for processing after extraction from forests; this can include fiber from both sound and cull trees. Harvest also describes cutting trees (e.g., clearcut harvest, partial cut harvest, harvesting, etc.).

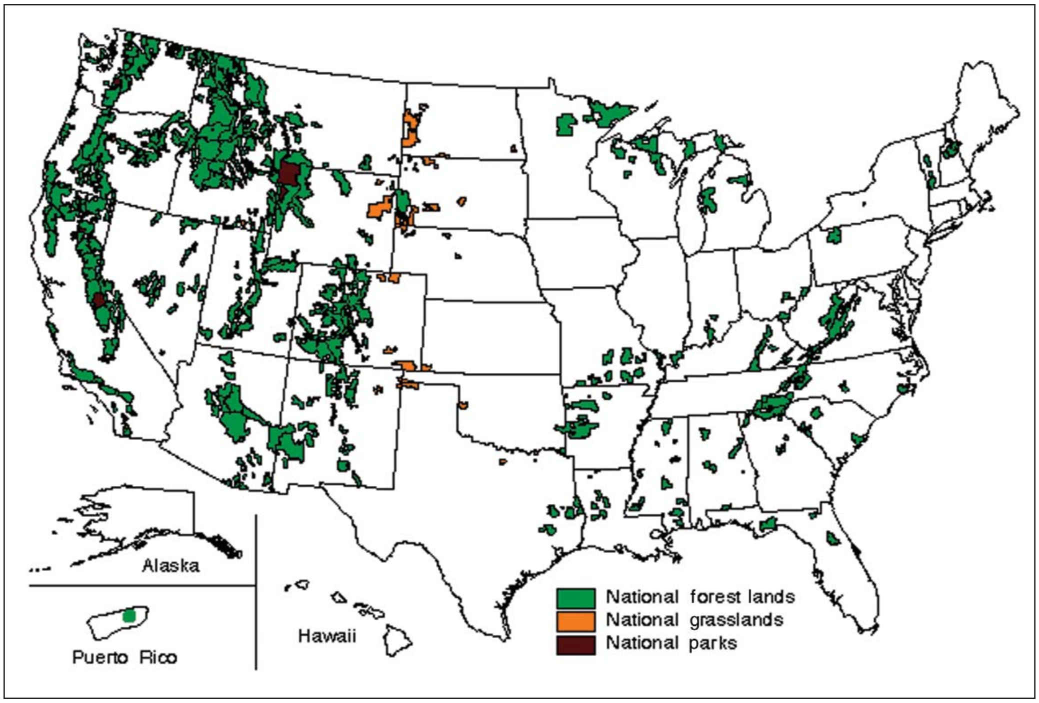

Figure 1—Distribution of national forests and parks.

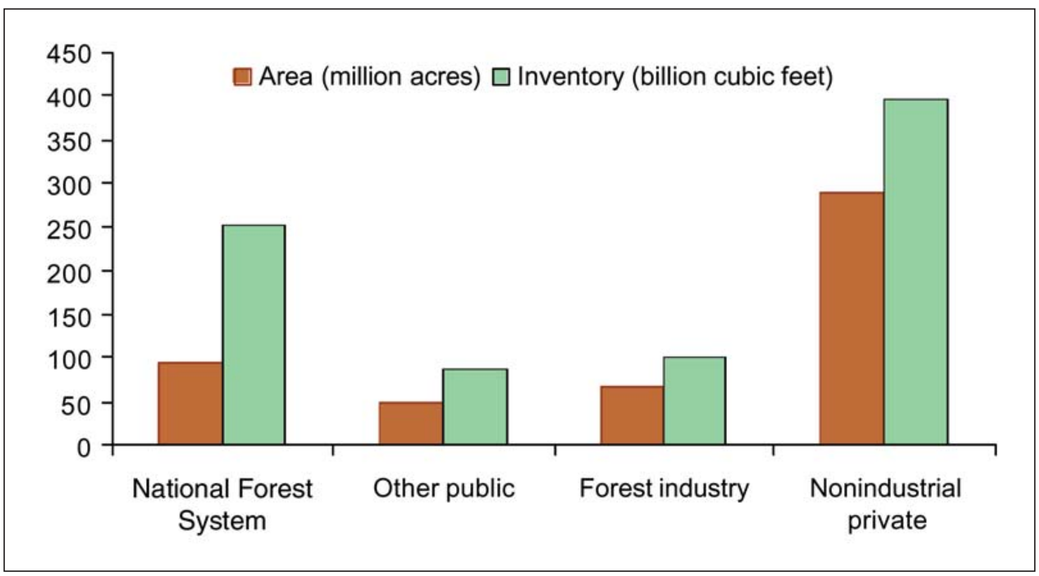

Figure 2—U.S. timberland area and inventory volume by ownership (1997).

The intent of this paper is to examine the projections of national forest timberland growth and volume by age and age-related seral stage and compare the results with the other U.S. timberland ownerships. The projections were developed with approximately the same level of detail as those made for private timberlands. One exception is that growth and yield regimes were not specifically identified for various management intensities to the extent they were for private lands in the South and Pacific Northwest (for details, see Haynes, in press). The forest planning effort is undergoing revision, so removals (or harvest) were not available from completed plans; to present a range of possibilities, five removals scenarios were defined.[4] Two of these scenarios are based on assumptions made in previous assessments, two were derived by using different approaches for the current assessment, and one is a no-harvest (zero cut) option. Also, the impact of large-scale disturbances was examined by including in the projections recent levels of fire, insects, and disease, and regeneration failures for two of the scenarios. The purpose of using removals projected in past assessments is to provide some perspective on how quickly the social and political forces shaping management policies are subject to change. The view of the future from 1989 was based on a very different set of assumptions than those used today.

The Projection Model

The model used for the inventory projections is known as the aggregate timberland assessment system (ATLAS; Mills and Kincaid 1992). This model was first developed for the 1989 timber assessment (Haynes 1990), and later updated for the 1993 assessment update (Haynes et al. 1995). In the assessment suite of models, ATLAS provides the framework projecting inventories by incorporating assumptions regarding forest growth and yield, timber management, harvesting, and changes in land use and forest cover. (For an indepth explanation of the timber assessment modeling system, see chapter 2 in Haynes, in press.) The modeling system has been adapted to project changes in forest growth rates associated with changing temperatures and rainfall for a national assessment examining the forest sector impacts of climate change (Joyce et al. 1995, Mills and Haynes 1995, Mills et al. 2000). Other studies, in collaboration with the U.S. Environmental Protection Agency, examined potential benefits consumers of forest products might experience because of stricter air pollution standards, specifically lower ozone levels (Bentley and Horst 1997, 1998). On a smaller scale, ATLAS has been used for specific state-level timber studies in both even-aged timber conditions of western Washington (Adams et al. 1992) and uneven-aged forests in Maine (Gadzik et al. 1998). The model was recently modified to meet the needs of the 2000 RPA timber assessment through an update of all inventories, associated growth parameters, and the expansion and integration of the available timber management options.

The projection system includes an inventory module, a management module, and a harvest module. The inventory module contains descriptions of inventory in terms of forest type, owner, site class (optional), management intensity (optional), and area

[4] Although some plan revisions are already completed, many forest or grassland plans are nearing the 15-year mark for revision mandated by the National Forest Management Act (NFMA 1976), and other forest or grassland plans are in the “maintenance” phase in which plans are amended. New planning regulations to guide the revisions are being evaluated internally and will soon be published for public comment (Zwight 2002).

and volume by age class. The management module contains the parameters governing growth and yield, including the hardwood-softwood fiber mix, average diameter by age, yield tables, regeneration stocking and density change variables, management intensity shift variables, harvesting parameters, and area change parameters. The harvest module contains future removals stratified by region, owner, and fiber type for each projection period.

This analysis is the first full implementation of ATLAS, or any age class model, with national forest timberland data. The projections made for previous assessments were based on simple growth-drain formulation, which satisfied the needs of the timber assessment market model (TAMM; Adams and Haynes 1980, 1996). For the simulations of private timberland, TAMM is used to derive removal levels from future stumpage demand, which comes from the projection of the future final forest product demand (lumber, plywood, oriented strandboard, pulp, paper, etc.). Removals are then passed to ATLAS identified by stumpage supply region, private ownership, and fiber type. When TAMM solves the market equilibrium in the private sector, fiber from national forests is included in the solution as an exogenous input. Market forces are not influencing management and harvest on NFS timberland as they do in the private sector. Thus, the process of finding the market solution does not need to interact with public inventory levels or growth rates.

Inventory Data

The data were derived from the database assembled for the 2000 RPA assessment (USDA Forest Service 1996).[5] These data are based on a set of measurements from permanent sample plots and compiled by researchers with the USDA Forest Service Forest Inventory and Analysis (FIA) units. In the Eastern United States, the plots on NFS lands were measured by FIA field crews, whereas the western data were collected by both FIA units and NFS inventory specialists and contract crews. The data are current for 1997; this means some previously measured plots were “updated” to approximate values that existed in 1997, and some corrections were made where documented errors existed. The compilation and analysis are consistent with the approach used to develop RPA projections for private timberlands (see Haynes, in press). The plot data are stratified by projection region, ownership, forest type, and age class. The assembled data represent the initial inventory starting point. Many of the required model growth and yield parameters are developed from the data. Details of regional and forest type definitions can be found in appendix table 8.

In the early 1990s, a change in data collection procedures on national forest lands occurred in most of the West. A new plot and grid system was initiated by FIA to collect inventory under a system compatible with a national design. This means western NFS data are now compatible with a system long in place on all private lands in the West and with the system previously established across all ownerships in the East. A drawback to the implementation of this system is that it imposes a new set of classification criteria on federal lands that were formerly under a map-based system of inventory. This makes it difficult to compare the new numbers with those published by using the older techniques. The tabular values presented for the West in 1991 and 1997 are not comparable in that they do not reflect real trends but result from the use

[5] Data are available on the Internet at http://www.fs.fed.us/pl/rpa/list.htm.

Table 1—Status of forest land on national forests by region, 1997

Region	Total forest land	Nonreserved		Reserved	
		Timberland	Other	Nonwilderness	Wilderness
	Thousand acres				
Pacific Northwest West	9,086.6	7,316.8	40.1	166.3	1,563.4
Pacific Northwest East	13,265.9	10,718.2	225.2	276.8	2,045.7
Pacific Southwest	16,747.7	10,086.0	2,928.3	378.8	3,354.6
Rocky Mountain North	30,968.7	23,955.9	910.2	67.1	6,035.5
Rocky Mountain South	41,256.1	19,537.3	14,850.9	309.1	6,558.8
North Central—Plains States	2,212.0	2,047.8	33.9	.0	130.3
North Central—Lake States	7,105.5	5,912.1	223.7	.0	969.7
Northeast	2,544.0	2,029.2	235.4	.0	279.4
South Central	6,870.2	6,457.2	11.3	.0	401.7
Southeast	5,469.9	4,594.3	52.4	1.1	822.1
Alaska	11,250.5	3,780.4	3,110.1	0.0	4,360.0
Total	146,777.1	96,435.2	22,621.5	1,199.2	26,521.2

of different systems. Inventories for the East and North have been carried out for several cycles with greater consistency, so differences between the 1991 and 1997 values for those regions reflect what are perceived as real changes in volume, growth, or timberland area.

Status of Forest Land

Forest land managed by the NFS is classified with a status of either nonreserved or reserved. As shown in table 1, the nonreserved status is subdivided to define potential uses. Public forests receive a wide range of use: some might be compatible on the same piece of land, such as hiking, hunting, grazing, and timber harvesting, but others are not compatible, such as timber harvesting and wilderness recreation. Timberland is land with potential for growing crops of industrial wood, whereas other forest land, owing to a combination of climate, topography, and soils, cannot support forests growing at the minimum commercial standard (see footnote 1). The uses for land in either of these categories might include recreation, wildlife habitat, and domestic livestock grazing, but it is assumed that commercial timber harvesting will occur only on timberland. The reserved category represents areas typically not available for commercial harvest but set aside for specific use(s). Wilderness typically allows specific types of recreation in association with preserved natural areas, and nonwilderness includes lands serving to protect resources such as significant ecosystems, species habitats, and municipal watersheds. These definitions are consistent with those used for private lands; however, the definition of reserved lands would rarely be applicable to privately owned land. Most of the reserved areas have not yet been inventoried for timber characteristics, but they contain a range from productive to nonproductive forests. For details see Smith et al. (2001).

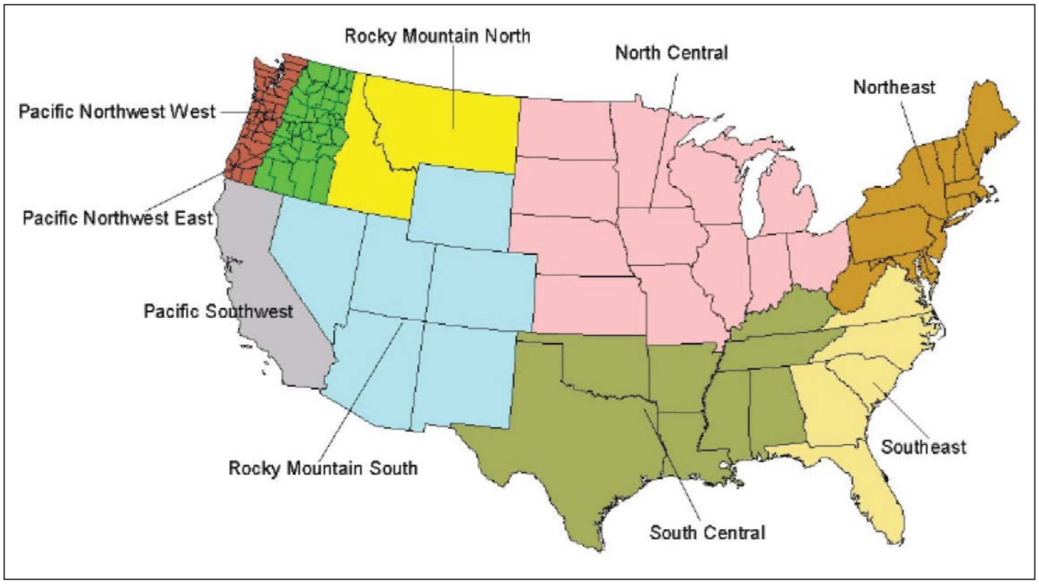

Figure 3—National forest inventory projection regions used in Resource Planning Act timber assessment.

The West plus Alaska accounts for 76 percent of all national forest timberland area and 86 percent of the total national forest timber inventory volume (the West includes the Pacific Northwest, Pacific Southwest, and Rocky Mountain regions; fig. 3). In contrast, the West supports roughly 14 percent of all private timberland area and 18 percent of the volume on private timberlands. Table 1 shows the Rocky Mountain South region comprising 41 million acres of forest land, which is 28 percent of all NFS forest land area (the most of any region), and 20 percent of NFS timberland. Owing to a combination of factors that influence climate (elevation, latitude, prevailing winds, and surrounding topography), roughly 36 percent of this region's forest is in the "other" less productive category, while another 17 percent is in the reserved category. This represents the largest contribution to both categories (66 percent of "other" and 25 percent of all reserved). In contrast, the Rocky Mountain North region is one of the most highly productive regions and second largest in terms of forest land area. About 77 percent of this region is timberland, which represents 25 percent of total NFS timberland, (the largest share of all regions), with just 3 percent falling into the "other" category. The Rocky Mountain North region also holds 22 percent of all reserved area, second to the Rocky Mountain South in terms of area in wilderness.

The Structure of Timberland Inventory

The composition of the inventory, in terms of timber volume, growth, and mortality, on timberland varies with differences in topography, associated mean temperatures, and rainfall patterns. Climate provides for growth potential, because forests are constantly being shaped by the effects of disturbances such as harvesting, insect infestations, disease, wildfires, and windstorms. These events create openings in stands or may remove the entire stand, which then is either naturally or artificially regenerated or replaced. Thus, climate influences the regional inventory, growth, and mortality rates presented in table 2.

The Pacific Northwest West region ranks fifth in timberland area, and it compares to the much larger Rocky Mountain North region in terms of inventory volume and annual growth while having just half the rate of mortality. A similar comparison can be made

Table 2—Inventory, net annual growth, and mortality on national forest timberland by region, 1997

Region	Timberland	Total inventory	Net annual growth	Annual mortality
	Thousand acres	- - - - - - - - - -	-*Million cubic feet*-	- - - - - - - -
Pacific Northwest West	7,316.7	52,878	843	209
Pacific Northwest East	10,718.2	23,993	322	265
Pacific Southwest	10,086.0	31,803	620	154
Rocky Mountain North	23,955.9	55,104	892	423
Rocky Mountain South	19,537.3	34,614	523	362
North Central—Plains States	2,047.8	2,181	48	14
North Central—Lake States	5,912.1	7,747	186	76
Northeast	2,029.2	4,478	82	34
South Central	6,457.2	11,645	336	63
Southeast	4,594.3	8,764	162	112
Alaska	3,780.4	18,909	89	124
Total	96,435.1	252,116	4,104	1,836

between the Pacific Northwest East and the Pacific Southwest regions, which are nearly equal in timberland area. Lower rainfall and a shorter growing season contribute to lower growth rates, higher mortality, and hence less inventory in the interior of Washington and Oregon than in California, where a large share of the timberland is influenced by warmer and wetter maritime conditions.

Reflecting the western distribution of national forests, 88 percent of the net growing-stock inventory volume on national forest timberland is softwood[6] fiber. This contrasts with 41 percent softwood composition on 356 million acres of private timberland.

The history of national forest management is reflected in the distribution of timberland by age class. Because public and private forest management objectives differ, it is likely that structural differences among ownerships will remain.

On a regional basis, national forests in the North (Northeast and North Central regions) have a higher concentration of hardwood species, with a hardwood fiber proportion of 68 percent, whereas the forests in the South (Southeast and South Central regions) have a high pine component and nearly the opposite inventory fiber composition at 65 percent softwood. Conifers dominate the West and Alaska where softwood is 96 percent and 99 percent of volume, respectively.

[6] Softwood and hardwood fiber is associated with the types of forest products that trees in these classes can produce. Coniferous species are generally called softwoods, whereas deciduous broad-leaved species are generally referred to as hardwoods.

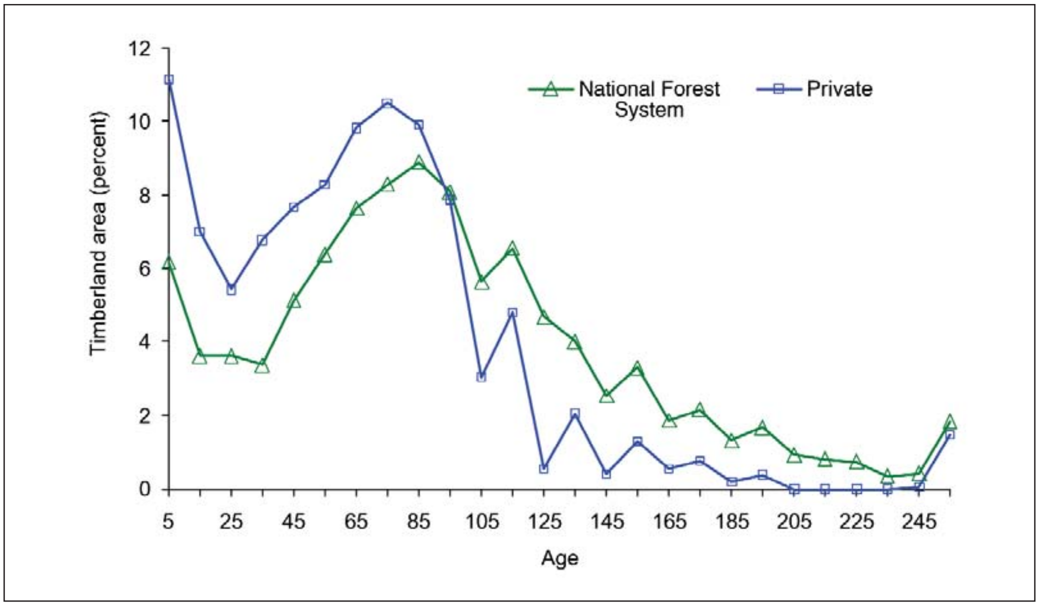

Figure 4—Timberland area distribution by stand age and ownership (all regions, 1997).

Age distribution of the inventory—Although many western tree species, principally conifers, can live more than 400 years (Burns and Honkala 1990, Franklin and Dyrness 1973), as figure 4 would indicate, the majority of the forests in the United States are relatively young. Roughly 62 percent of national forest timberland and 84 percent of the timberland in private ownership supports stands of trees less than 100 years old. Older forests occupy smaller portions of the landscape; stands of 150 years and older account for 15 percent of national forest timberland and about 3 percent of private timberland.

Seral stage of the inventory—Seral stage describes the ecological succession in plant communities, typically ranging from a young or early stage to an old or late stage. From a biological context, seral stage considers stand size, species composition, stand density or stocking, and the amount of dead and down material in the stand. In context of the projections presented here, as stands grow older the average tree size and stand volume increase. Older trees and older forests have typically achieved a greater degree of succession than younger forests. The FIA correlates age and tree size to a product class associated with the types of forest products a stand could potentially produce. In table 3 we present a modified form of the FIA seral stages based on size-product class (Powell et al. 1993) with five categories. These categories are based on the assumption that stands in the South reach maturity at younger ages than stands do in either the West or the North. The starting timberland inventory is stratified by these seral stages in figure 5. The majority of mature and older forests in the United States are found in the West, and smaller portions are found in the South. As in the West and North regions, however, mature sawtimber is the largest class in the South region.

Forest types—Plots are aggregated and classified by forest type. Each type is a composite of many species that often occur together under similar conditions. Inventory plots typically include measurements from more than one tree species. The FIA units

Table 3—Seral stages based on age associated with forest products classes

Seral stage	West Softwood	West Hardwood	North Softwood	North Hardwood	South Softwood	South Hardwood
			Stand age (years)			
Seedlings	5	5	5 to 15	5	5	5
Saplings and poles	15 to 35	15 to 35	25 to 35	15 to 35	10 to 15	10 to 20
Young sawtimber	45 to 75	45 to 55	45 to 65	45 to 65	20 to 35	25 to 55
Mature sawtimber	85 to 135	65 to 135	75 to 135	75 to 135	40 to 75	60 to 75
Old mature sawtimber	145+	145+	145+	145+	80+	80+

Source: Haynes, in press.

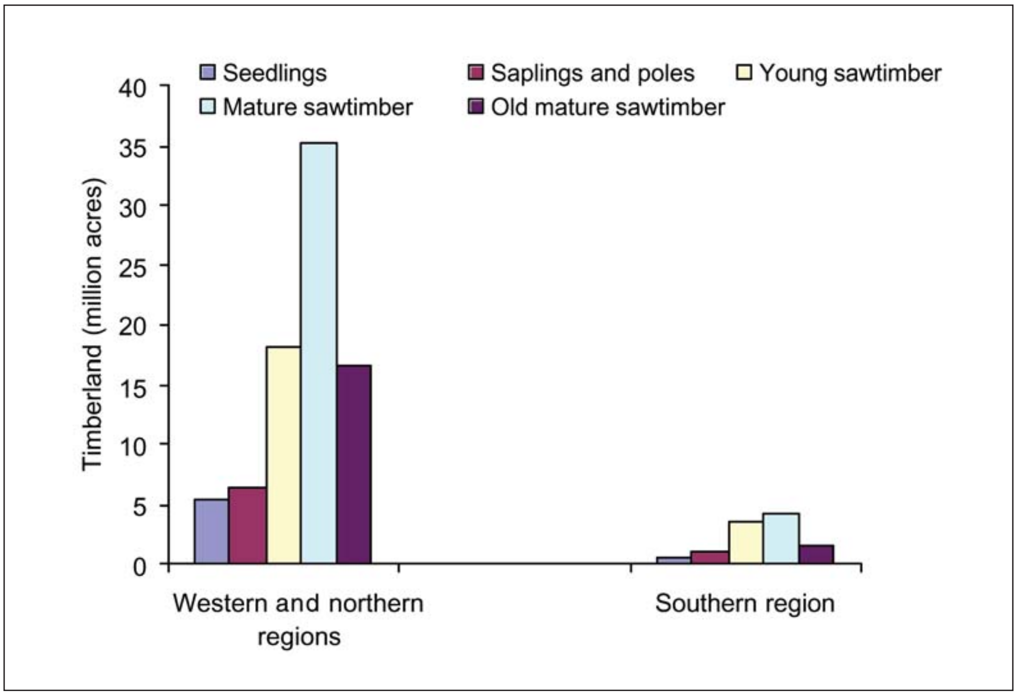

Figure 5—National forest area distribution by stand seral stage (1997).

compute the contribution of stocking by individual species when assigning a forest type to the plot. For projection purposes, it is assumed the plots within a forest type can be assigned similar growth and yield characteristics. This understates the large site variance among plots, but over a region we are seeking an answer that represents a set of averages. Up to 10 forest types were assigned to each region, and, in general, they are the same as those assigned for the private ownership. For growth modeling purposes, some forest types with few plots may be grouped with a type exhibiting similar growth characteristics.

Table 4—Regional dominance of forest types on national forest timberland by region, 1997

Region	Most dominant forest types by region
	Percentage of timberland
Pacific Northwest West	Douglas-fir (50.2), fir and spruce (22.0)
Pacific Northwest East	Ponderosa pine (33.6), Douglas-fir and larch (24.4)
Pacific Southwest	True fir (28.0), mixed conifer (23.5)
Rocky Mountain North	Douglas-fir (41.1), fir and spruce (25.6)
Rocky Mountain South	Ponderosa pine (31.1), fir and spruce (25.3)
North Central—Plains States	Oak and hickory (71.4), pines (12.2)
North Central—Lake States	Aspen and birch (27.6), maple and beech (26.1)
Northeast	Maple/beech/birch (51.1), oak and hickory (21.0)
South Central	Upland hardwood (37.0), natural pine (30.2)
Southeast	Upland hardwood (50.2), natural pine (22.3)

The complete set of forest types recognized is presented by region in appendix table 8. The major forest types for each region are presented in table 4. It is interesting that in most regions, 50 percent of the timberland area is composed of just one or two forest types. For example, 50 percent of the inventory in the Pacific Northwest West region is in the Douglas-fir (see table 30 for species names) forest type, and 50 percent of the Southeast is upland hardwood (a mix of upland site trees including white and red oaks, hickory, the chestnut oak type, yellow-poplar, elm, maple, and black walnut).

Modeling Assumptions

The projections of national forest timberland inventories rest on a set of assumptions. These assumptions are associated with interpreting, compiling, and analyzing resource data for the parameterization of the modeling framework.

Age classes—The timberland in the Northeast, South Central and Southeast regions was stratified by 18 age classes. Because the western national forests generally support some of the oldest forests, they were stratified by using 26 age classes in an effort to better identify potential late-seral stage conditions. A 10-year interval for age class was used for all regions except for the Southern regions, where the inventory was aggregated into 5-year classes. The FIA plot data did not contain an assigned stand age for about 38 percent of the plots in the Northeast and some plots in the South Central regions. Age class was assigned with a technique that considers volume and stocking in the same way ages were assigned to the private FIA plots in these regions. All private timberland projected for the assessment was stratified in 18 age classes, by using 5-year intervals in the South and 10-year intervals elsewhere.

Yield functions—Each inventory cell in ATLAS is projected relative to a base yield. A set of base yield tables was derived for each forest type within each region from the FIA plot data. This technique was developed in past assessments to produce aggregate growth yields (Mills 1990) for particular types when other sources were neither available nor representative across a region. This use of empirical growth rates embodies the effects of historical and recent management practices. This study used a series of regressions conducted to predict net growth by age for each regional forest type. The yields were then an accumulation of net annual growth; the following represents the approach for a 10-year interval age classification:

Age class	Net growth	Yield
0	G_0	$Y_0 = 0$
1	G_1	$Y_1 = [(G_0 + G_1)/2]5$
2	G_2	$Y_2 = [(G_1 + G_2)/2]10 + Y_1$
3	G_3	$Y_3 = [(G_2 + G_3)/2]10 + Y_2$
4	G_4	$Y_4 = [(G_3 + G_4)/2]10 + Y_3$
…	…	…

Where
G_{ac} = net annual growth at age class ac, and
Y_{ac} = Yield at age class ac.

The variable Y_{ac} represents the net growing-stock volume at the age class midpoint (e.g., at ac=0, age=5; at ac=1, age=15; and when ac=2, age=25; etc.). The general model of the net growth (G) for age class (ac) is expressed as G = F(ac). The example of the net-growth function of the Douglas-fir forest type for the Pacific Northwest West region for age classes greater than zero (ac>0) is:

$$G_{ac} = 1002.8 + 41.5ac - 0.71\ ac^2 - 391.2Ln(ac) - 305.1e^{(1/ac)},\ \ (ac>0). \qquad (1)$$

In regions with very few observations on national forests, yields were constructed with the addition of FIA plots from private lands. Figures 6 and 7 compare yields developed for private timberland on medium-productivity sites with the national forest all-site yields. In the first case, the Douglas-fir yields were developed with two independent data sets; the data were collected at different times, and no plots were in both sets. It is interesting to note how the national forest growth rate begins faster than the medium-site private lands, but then slows with age, crossing at roughly 110 years of age. The Southern planted pine yield represents an overlapping situation where, because of fewer observations, the NFS yields were developed with plots from both NFS and private lands. The Southern national forest values (fig. 7) were calculated with all timberland plots, whereas the private yield was derived from only timberland plots classified as medium site productivity. It is interesting to note how well the medium site class represents the overall average for national forest lands. The complete set of yields developed for each region can be found in appendix tables 9 through 17.

If the future is significantly different than the past, then this approach is subject to bias; for instance, atmospheric pollution, climate change, and use of improved genotypes can compound errors associated with using empirical data to project stands forward (Adlard 1995). We normally handle these unknowns by making assumptions in various scenarios. In the case of national forests, the largest effect on future inventories is likely to be the level of disturbance, namely insects, fire, and harvest.

Mortality—In a stand with differential tree growth, as canopy closure occurs, the slower growing trees become suppressed, accelerating their weakening and leaving them less resistant to the effects of weather (drought and wind), insects, and disease

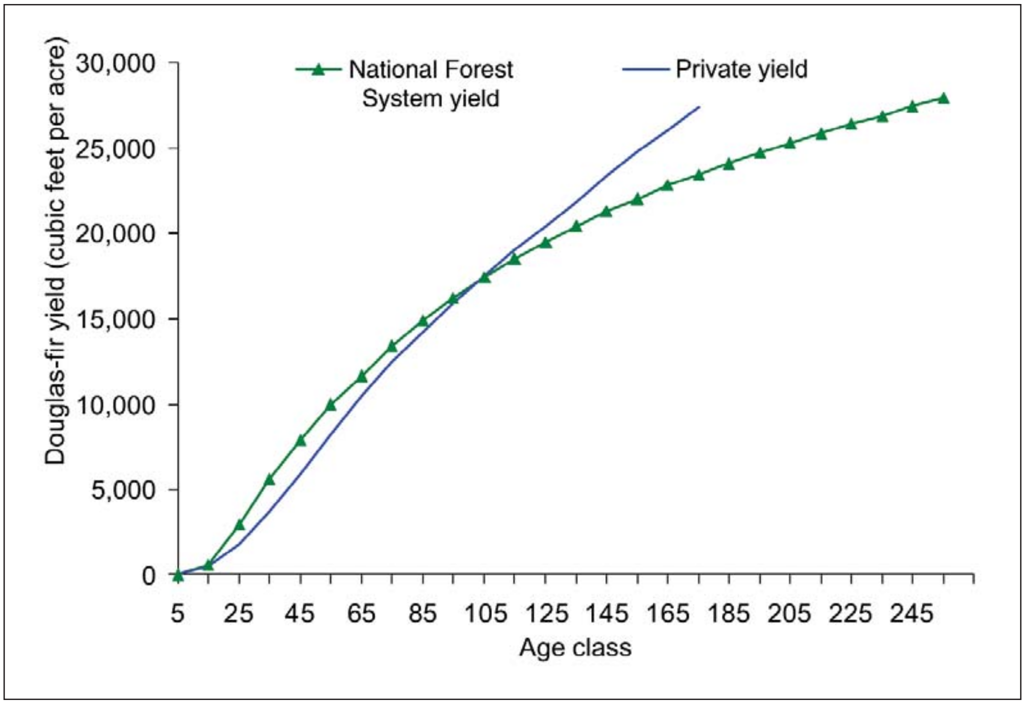

Figure 6—Douglas-fir yields in the Pacific Northwest West region, comparing national forest and medium-site-productivity private ownerships.

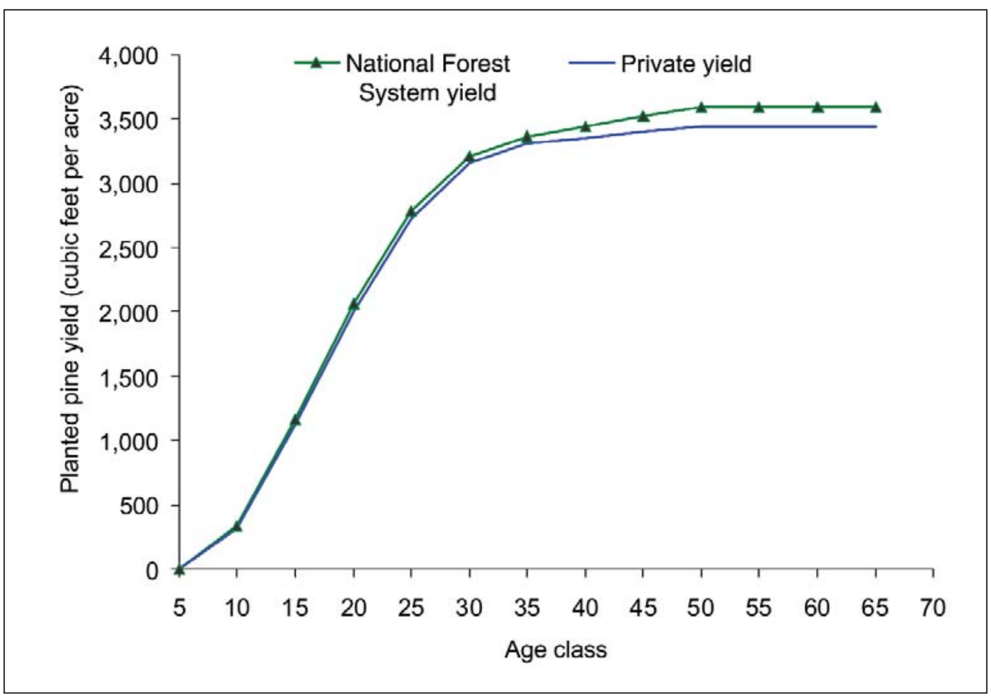

Figure 7—Planted pine yields in the South Central region, comparing national forest and medium-site-productivity private ownerships.

(Oliver and Larson 1990). So as forest stands age and average tree diameter increases, the number of living trees in the stand typically decreases owing to mortality of trees unable to compete for the limited resources (Davis and Johnson 1987). Oliver and Larson (1990) identify two categories of mortality, “regular mortality” and “irregular mortality.” On a landscape scale, regular mortality is part of forest succession, occurring as trees age and compete with each other for light and water. Meanwhile, irregular mortality is associated with disturbances such as fire, insect epidemics, or disease that kill what are otherwise healthy trees. Mortality is measured in successive surveys as the volume in the trees that have died over a fixed time interval. As shown in table 2, the most recent accounting for annual mortality indicates it is less than one percent of standing inventory volume.

The starting (1997) forest inventory data were compiled by FIA to represent net values (live growing stock) for all volumes (growth, inventory, removals), and the projections represent net values as well. Net growth is the total increment from growth (gross growth) over a period, minus the volume of wood in trees that have died during that period (see Smith et al. 2001). Using net values to calibrate the growth models is an implicit approach to considering mortality. For example, the growth and yield relations were developed from a cross section of field plots, many of which represent stands that would be expected to have histories with various levels of mortality. For a few plots, net growth was reported to be a negative value, meaning the volume of mortality exceeded the gross increment from growth. This would likely indicate a recent disturbance to the stand. These plots were included in the process to calibrate net inventory growth, so this background level of mortality is part of the projection. On a landscape level, we assert that these projections reflect the average rate of historical mortality.

Disturbance—Oliver and Larson (1990) associate irregular mortality with disturbances that occur less frequently than regular mortality, kill or injure otherwise healthy trees, and potentially leave entire stands damaged or destroyed. Depending on the stage of stand development, when these disturbances are large enough to leave gaps in the canopy, new vegetation may take root or surviving trees may grow into the available space. In managed stands, these gaps or areas are typically artificially regenerated. Past projections using ATLAS have not explicitly included stand-replacing events that are large enough to be measured and associated with either catastrophic fires or large insect outbreaks. Stand-replacement disturbances are typically followed by either natural or artificial regeneration, and the composition of the next forest potentially could be different than predisturbed conditions (e.g., the loss of a mixed pine-fir stand replaced by planting ponderosa pine). From a modeling perspective, these mortality occurrences can be treated like a form of harvest, where the entire stand is removed, followed by regeneration. This acts to shift the local age-class distribution toward younger stages.

The Forest Service keeps a record of the timberland area in need of reforestation and identifies the cause.[7] Figure 8 shows that until recently, the largest additions to the national forest “reforestation needs” pool were due to harvest. Since 1987, as

[7] Data source is *Reforestation and Timber Stand Improvement Needs Report* (FS-2400-K) Table 1, as required by the National Forest Management Act of 1976, Sec.4d(1).

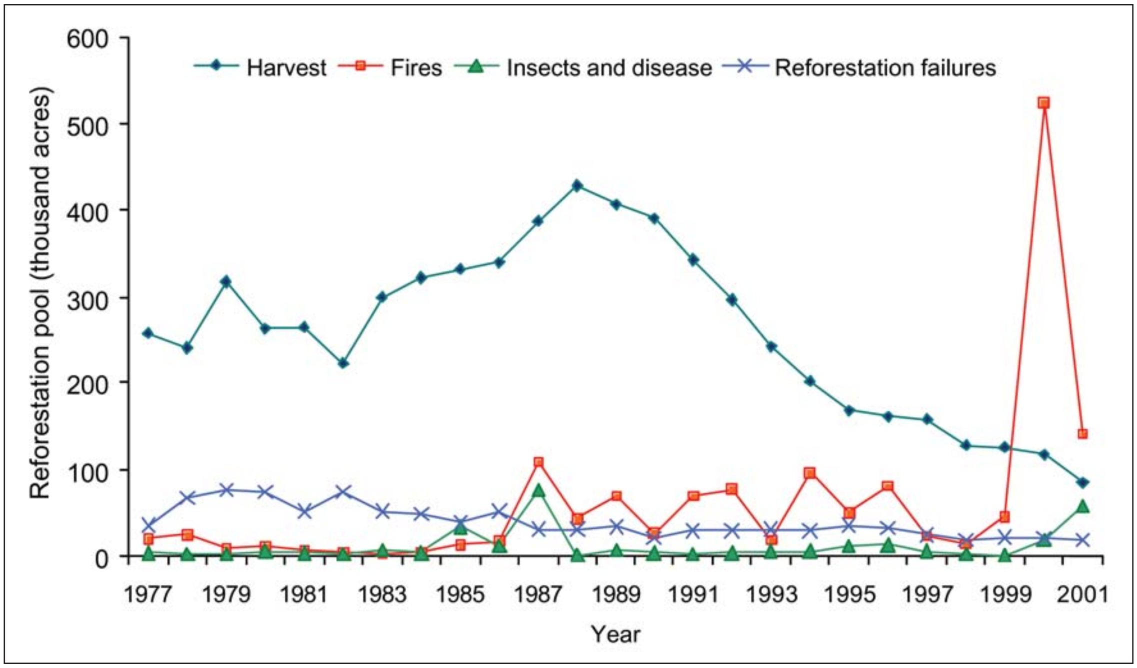

Figure 8—Annual additions to the national forest reforestation needs pool, by cause.

removal levels dropped, the additions from harvest fell, while at the same time additions from the area burned in fires increased. Although the year 2000 was dramatic in terms of area burned, in 2001, fires also exceeded recent history,[8] while at the same time additions from insects and disease outbreaks rose to nearly equal the level of additions from harvest. To address the issues associated with the redistribution of acres affected by this irregular mortality, two projection scenarios were modified to incorporate the explicit return of deforested area to the regeneration pool following these losses. Although regeneration failures might not be classified as a form of mortality linked to a disturbance, they are included here because the area accounted for is too large to ignore, being more acres than additions from insects and disease. These scenarios incorporate and project additions to the reforestation/regeneration pool at the average rate they occurred in the most recent 10 years (1992 through 2001). These disturbances require the model to regenerate an additional 140,000 acres annually.

Modeling disturbance—The base case and zero cut scenarios were run with the explicit addition of disturbance. The disturbance values were based on historical averages and calculated by region. In each 10-year projection period, a total of 1.4 million acres was added to the regeneration pool. Several assumptions were made about the forest types and age classes impacted. The disturbance was proportioned in each region among the two most dominant forest types, those covering the largest area (table 4). The predisposition of a stand to different disturbances changes with the stand structure and type of disturbance, but generally increases with age (Oliver and Larson 1990). Therefore, the impacts were distributed across stands at or greater than

[8] As this publication went to press, wildfires in 2002 had exceeded the area of Forest Service timberland burned in 2000.

the minimum harvest age class. The allocation was in proportion to existing area by age class. As for a clearcut harvest, it was assumed that disturbed stands would be managed for regeneration. Volume was removed from impacted acres, and the area was returned to the regeneration pool. Unlike harvest volume, however, the volume affected by disturbance was counted as mortality, and subtracted from growth to generate a new net growth value. Regeneration failures also were calculated by region and projected for the two predominant forest types. The failed regeneration acres were lagged, meaning they remained in the zero age class for an extra 5- or 10-year period. Once in the pool, it was assumed that the action that preceded lands moving there was irrelevant, and both harvested and disturbed acres were treated the same. Lacking data on pre- and post-disturbance forest types, all regenerated stands returned to the same forest type from which they originated.

Management intensity—The NFS projections apply three management regimes that differ by the approach to harvest. The first allows regeneration harvest; that is, a final harvest or clearcut will occur in these stands over a range of ages followed typically by the planting of seedlings. The second regime was developed to apply a partial harvest—this treatment removes a portion of volume to mimic a stand subject to multiple entries. The third management option is labeled reserved, as these stands are projected forward in time but not harvested. The number of acres assigned to these regimes was derived from a survey of national forest regional silviculturists coordinated by Frank Burch (1999), which requested information on the amount of volume to be removed by forest type, and the harvest method. Acreage estimates were derived by applying average per-acre harvest outputs by harvest method in each forest type.

Likewise, when the projection begins, the number of acres treated depends on relative available volume within a particular regime. Harvest is allowed to occur at younger ages in the South than in the West, reflecting local customs based on the rate at which stands mature into various product classes. Adding disturbance to the base case scenario did not change the amount of volume removed in harvesting, as no assumptions were made regarding the salvage of dead material. The disturbance was applied before cutting, which lowered the volume available for cutting in the affected forest types.

Area change—The area of national forest timberland is assumed to remain unchanged for the next 50 years. The model is flexible for implementing area and forest type changes, but for public lands these transitions are occurring more slowly than on private lands where urbanization, agriculture, changing land ownership, and management objectives play a dynamic role in shaping timberlands. In the past 20 years, the NFS land available for commercial timber projection has declined significantly, and future changes in the “suitable” land base could have a marked impact on available timberland. It is assumed that the national forest area base will be subject to relatively small changes in the future, as land acquisitions and trades do occur, but not to the extent as to significantly impact regional projections.

Site class—National forest timberland covers a range of site productivity from 20 to more than 225 cubic feet of net growth per acre per year as measured at the culmination of mean annual increment. Most NFS timberland in the Pacific Northwest West produces over 120 cubic feet per acre per year, whereas other regions generally produce less. If the productivity of NFS timberland is ranked among other ownerships, forest industry has the most productive lands, followed by NFS timberland, NIPF owners, and other government ownership.[9] The poorest NFS sites are typically found on lands classified in the nontimberland categories.

Site productivity was a stratification variable for the projection of private inventories in the South and Pacific Northwest where management regimes were customized for three aggregate classes of site productivity (e.g., treatments were generally scheduled at younger stand ages for high vs. low site productivity timberland). Because the projected NFS management regimes were not tailored specifically to site, this stratification would not improve or even change the outcome.

Other parameters—Several other parameters are required for an ATLAS projection. These contribute to the calibration of growth, the assignment of stocking upon regeneration, the proportion of hardwood and softwood fiber in the inventory, and the descriptive variables such as average diameter by age. These empirical values were derived from variables in the FIA plot data (see Mills 1990 for their relevance).

Excluded timber and forest lands—Although presented in the tabulations, projections did not include lands classified as timberland officially reserved (not to be confused with the "reserved" management intensity class) or lands classified as nonproductive forest land. These areas are important contributors to ecosystem diversity, provide wildlife habitat, sequester carbon dioxide from the atmosphere, and provide utility for human uses. Data are not yet available to project the forests in these areas. As data become available, future projections will likely include these lands for various holistic studies.

Projection Scenarios

The future levels of timber removals in national forests will be developed with tools of science and planning and with direction and input from the interactions among the three branches of federal government, regional and local managers, and the American public. During the 1990s, timber removals from national forests decreased dramatically from the higher levels mandated by Congress in the late 1980s. The de-emphasis on timber production has occurred as the management focus has broadened to consider a variety of other resource issues including the preservation of threatened, endangered, and sensitive wildlife species and complex questions relating to ecosystem health and integrity. To examine a range of possible outcomes, and address both past and current trends, projections were made by using five removals scenarios. Two scenarios represent the current best estimates by Forest Service personnel, two scenarios reflect assumptions made as part of the 1989 and 1993 timber assessments, and the final projection assumes no commercial timber removals. The removal numbers were developed to provide input for the timber demand model used in the assessment (TAMM), so the values were stratified by softwood and hardwood fiber and aggregated to the RPA timber supply region.

Scenario one is labeled the "base case." The removals were derived from compilations done at the Forest Service Washington Office (WO) specifically for use in the 2000 RPA timber assessment. These values are normally derived through the forest

[9] As calculated by using area and site productivity class and timberland area from the 1997 RPA database.

planning process, but at this time, many plans are 10 to 15 or more years old, and the agency is in the process of overhauling the regulatory framework that will guide their revision.[10] This set of removals represents the current expectation based on the guidelines of Forest Service policy. This scenario was run both with and without the major disturbance regime.

Scenario two is based on a survey of Forest Service regional silviculturists conducted in 1999 by Burch (1999). These values were derived independently of the effort to predict the removals used in scenario one. The silviculturists were asked to apply their best professional judgment in making a two-decade projection of future removals. Lacking completed forest plans, the regional analyses were predicated on two important assumptions: (1) volume outputs in full compliance with existing laws, regulations, plan direction, and agency policy; and (2) static budget and staffing levels for preparing and administering timber sales and for the implementation of vegetation management programs over the analysis period. Most respondents estimated that the removals in the second decade would be the same as the first. The estimates were made for the aggregate forest types that matched the FIA inventory data as projected in the model. The removals were provided in board feet, which were converted to cubic feet. This conversion used FIA data to calculate a ratio by region and fiber type (softwood or hardwood); values ranged from roughly 5.8 to 1.4 board feet for 1 cubic foot. When projected, the removals provided for the second decade (2010-2020) were held constant through 2050.

Scenario three allocates the highest level of removals because it was originally the base scenario for the 1989 RPA timber assessment, which was developed near the end of the period when the Forest Service removals reached all-time highs. In that assessment, the predicted removals covered the years of 1990 to 2040; however, this analysis extends the later values to 2050. Public attitudes, values, and expectations have changed in the short time since that assessment. It is difficult to judge if the agency will ever return to a policy of these levels, so it might be safe to assume this removal scenario represents an upper bound in considering the resulting projections.

Scenario four follows the removal levels predicted for the 1993 RPA timber assessment update. By this time, harvesting was dramatically scaled back in the Pacific Northwest to meet the requirements of the Northwest Forest Plan. Those values reflected management considerations for wildlife habitat that dropped the projected removals to almost half of the level assumed in the 1989 assessment. This level of removals falls between 1989 RPA projection and the current RPA expectations.

Scenario five simply assumes no commercial removals, the zero cut scenario. It was developed to examine the NFS inventory structure after 50 years with no commercial harvesting and to highlight the ecosystem consequences that include a lack of commercial-scale regeneration work. The result is a “forward movement” in the age class structure. As stands age without replacement, a gap forms as there is a decline in the area supporting stands in early-seral stages. Given what we know about natural processes, this situation seems not only unrealistic, but as a management objective it

[10] Updated information can be found through links on the Forest Service Web site at http://www.fs.fed.us/.

would seem to be unachievable—stand-replacing events occur naturally. To examine this, the scenario was run both without and with major stand-replacing disturbances, and it was assumed disturbance would be followed by regeneration.

Figure 9 shows the array of projected removals displayed with the historical removals that occurred between 1952 and 1991.[11] Strikingly apparent are the large gaps between the projected removals levels for each successive assessment. In a relatively short time, an evolution in public thinking occurred that resulted in policies greatly affecting our views of the future. Removal levels today are somewhere near the levels of the base and Burch cases—a steep decline from the 1991 historical level and much steeper than the increase that came after 1952.

In our examination of the scenarios based on past assessments (scenarios three and four), we are not projecting them from their inception in 1989 or 1993, but from the inventory we have today (dated 1997). The level of removals assumed in those scenarios from 1989 or from 1993 forward did not occur, and it is likely the 1997 inventory has grown larger than it was in the early 1990s. If we were to truly follow past assumptions, it would require the 1997 "initial" inventory to be estimated based on the 1989 or 1993 projections of anticipated removals. We also did not include disturbance in combination with the past assessment scenarios. The average rate of disturbance was derived over a period when removals were significantly lower than those projected under the third and fourth scenarios, and we assumed a correlation may exist between disturbance and removals. Given the data presented here, that is difficult to judge, however, as figure 8 shows that, for 1977 to 1987, second only to harvest, the biggest reason for planting trees was regeneration failures, not natural disturbance. In this short period, the graph shows that natural disturbance rose as cut levels and the regeneration backlog declined (we acknowledge that "natural" disturbance is highly influenced by weather, accidents, and arson[12]). Disturbance was also not added for scenario two because it was similar to the base, which incorporated disturbance.

The lowest base case removals are for the year 2010, where the 623 million cubic feet (mcf) is just 30 percent of that projected by the 1989 assessment. Farther out, the 1989 assessment projection for softwood removals in 2040 rises to 1,935 mcf, whereas today, expectations are closer to 735 mcf. The 1993 assessment captured the legal mandates of the early 1990s, when the softwood removals in 2010 were expected to be 932 mcf, which is 27 percent higher than current projections. Today, the largest reductions from the 1989 and 1993 assessment projections are found in the Rocky Mountain, Pacific Northwest West, and Pacific Southwest regions. The softwood removals in 1997 for Pacific Northwest West were just 25 percent of the level harvested in 1991.

Projection Results

The inventory volume projected for softwood and hardwood forest types differs by region, but in all scenarios, the total volume rises. Figure 10 shows a snapshot of the projection results for 2050 by scenario and region. Tables 5 and 6 present details

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[11] In all scenarios, Alaska removals remain unchanged at the base case level.
[12] Statistics available for 7 years from 1984 through 1990 show that 89 percent of all wildfires had human origins, but 50 percent of the area burned was by wildfire originating from lightning (USDA Forest Service 1992).

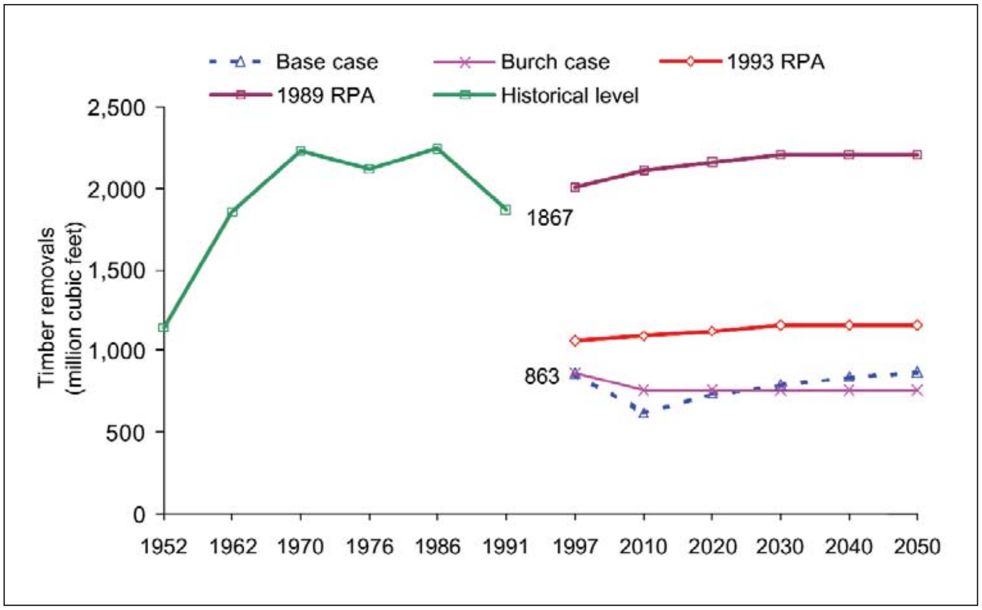

Figure 9—Historical and projected timber removals for national forest timberland.

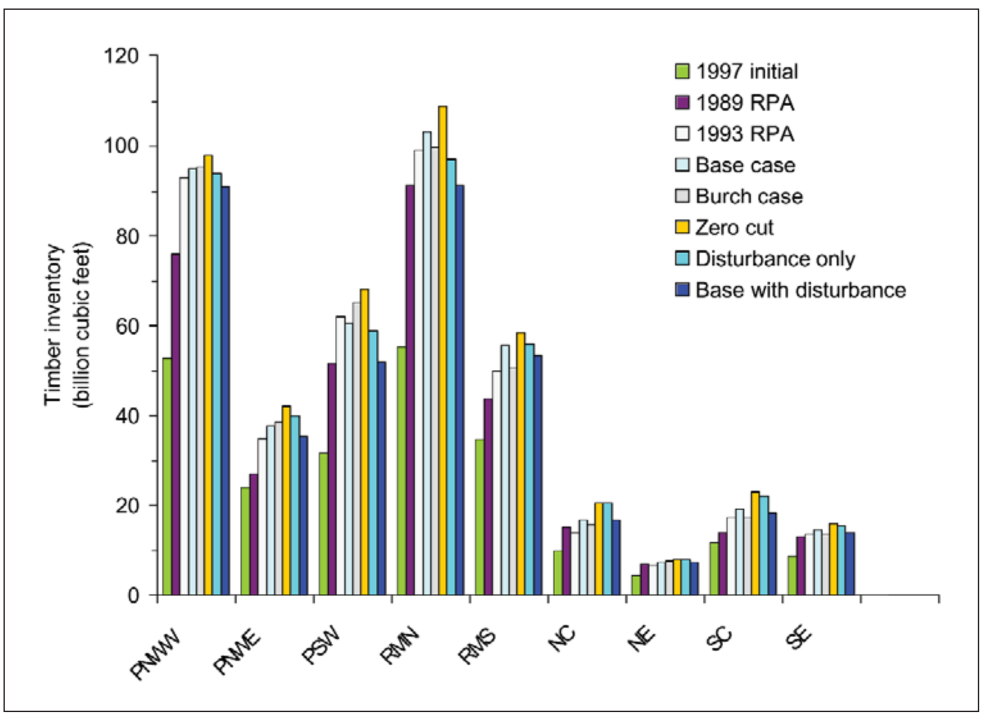

Figure 10—Initial and projected inventory for 2050 by region and scenario. PNWW is Pacific Northwest West, PNWE is Pacific Northwest East, PSW is Pacific Southwest, RMN is Rocky Mountain North, RMS is Rocky Mountain South, NC is North Central, NE is Northeast, SC is South Central, and SE is Southeast.

Table 5—Softwood inventory, annual removals, and net annual growth projected for national forest timberland under the base case with disturbance scenario

Region	1991	1997	Projections				
			2010	2020	2030	2040	2050
			Million cubic feet				
Northeast:							
Removals	5	5	5	4	5	4	5
Inventory	723	782	1,043	1,117	1,181	1,240	1,292
Net annual growth	17	14	12	11	11	10	10
North Central:							
Removals	48	25	25	26	27	28	28
Inventory	3,216	3,646	4,558	5,039	5,438	5,749	6,038
Net annual growth	84	95	75	70	59	57	56
Southeast:							
Removals	59	47	28	35	36	36	36
Inventory	2,826	2,991	4,067	4,539	4,759	4,885	4,985
Net annual growth	50	57	95	67	52	46	45
South Central:							
Removals	169	139	77	93	94	93	93
Inventory	6,013	6,396	7,404	7,893	8,165	8,407	8,615
Net annual growth	174	192	148	126	119	117	111
Rocky Mountains:							
Removals	389	130	142	172	183	193	200
Inventory	71,657	84,925	100,236	111,467	120,897	128,473	134,534
Net annual growth	1,285	1,273	1,317	1,174	990	836	719
Pacific Southwest:							
Removals	314	96	108	132	139	145	148
Inventory	31,448	29,539	35,217	39,098	42,610	45,850	48,809
Net annual growth	463	616	508	491	472	448	427
Pacific Northwest West:							
Removals	266	66	49	63	74	86	94
Inventory	33,621	51,399	61,909	69,432	76,266	82,401	88,008
Net annual growth	320	778	861	793	714	678	639
Pacific Northwest East:							
Removals	330	72	68	87	103	120	130
Inventory	17,338	23,915	28,039	30,992	33,517	35,642	37,418
Net annual growth	269	320	335	308	282	264	249
Alaska:							
Removals	99	51	29	29	29	29	29
Inventory	18,733	18,733	19,290	19,847	20,404	20,961	21,518
Net annual growth	85	85	85	85	85	85	85
United States:							
Removals	1,679	629	531	641	690	735	792
Inventory	185,575	222,326	261,763	289,424	313,237	333,608	351,217
Net annual growth	2,747	3,430	3,437	3,125	2,784	2,542	2,342

Table 6—Hardwood inventory, annual removals, and net annual growth projected for national forest timberland under the base case with disturbance scenario

			Projections				
Region	1991	1997	2010	2020	2030	2040	2050
			Million cubic feet				
Northeast:							
Removals	22	17	8	10	10	11	11
Inventory	3,711	3,696	4,230	4,729	5,184	5,605	5,986
Net annual growth	69	60	56	53	50	46	
North Central:							
Removals	61	64	44	45	46	47	47
Inventory	5,228	6,282	7,919	8,893	9,559	10,134	10,657
Net annual growth	123	139	153	115	105	100	97
Southeast:							
Removals	13	51	9	10	10	10	10
Inventory	5,565	5,773	7,293	8,025	8,478	8,768	8,967
Net annual growth	114	105	101	70	46	34	27
South Central:							
Removals	36	56	24	29	30	30	30
Inventory	4,959	5,249	6,971	8,018	8,857	9,485	9,860
Net annual growth	147	144	138	125	105	80	59
West:							
Removals	54	11	6	7	8	8	9
Inventory	6,178	8,613	10,592	12,211	13,522	14,746	15,969
Net annual growth	71	214	180	143	130	132	127
Alaska:							
Removals	N/A	0.4	0.3	0.3	0.3	0.3	0.3
Inventory	N/A	176	21	252	290	328	366
Net annual growth	N/A	4.1	4	4	4	4	4
United States:							
Removals	186	199	91	102	104	106	106
Inventory	25,641	29,789	37,219	42,128	45,890	49,066	51,805
Net annual growth	543	674	636	511	443	400	361

N/A = not available.

regarding growth, removals, and inventory for the base case with disturbance scenario, and results from all other scenarios can be found in appendix tables 18 through 29. In total, the volume increase from 1997 to 2050 ranges from about 45 percent with the 1989 assessment assumptions to 90 percent under the zero cut no-disturbance scenario. This translates to increases that range from between 105 and 210 billion cubic feet of additional timber (net growing stock). Of all the scenarios, the 1993 assessment projection falls roughly in the middle. It is interesting that the volume trajectories that match each other most closely are the base case without disturbance and the zero cut case with disturbance. This means the losses from disturbance have an aggregate impact on the inventory as large as the removals assumed for base case. When disturbance is then added to the base case, the projection falls 3 percent below the 1993 assessment scenario making the base with disturbance the second lowest in terms of total projected volume in 2050.

The results by region are uneven because of the independence of growth rates, removals, and disturbance. Whereas growth and disturbance are tailored to the region, removals differ independently in each scenario. For example, softwood removals are highest under the 1989 assessment assumptions, and they range initially (1997) from 10 times the base case in the Pacific Northwest West to 52 percent above the base case in the Northeast. By 2050, the difference in removals in the Pacific Northwest West has narrowed to four times the base case, while strong softwood growth helps to push inventory up by 40 percent. The biggest cap on inventory under the 1989 assumptions can be noted in the South Central region, where softwood removals begin 137 percent above the base case and gradually drop to 85 percent above the base; initially the inventory increases, but after 2010 the removals are high enough to push inventory down, and by 2050 it is within 2 percent of the starting volume.

The inventory outcome of the base (without disturbance) and the Burch projections were very close, but their removals levels differ. The Burch removals remain constant after the first 10 years, averaging 816 mcf per year; the base case removals tend to increase over the projection, starting at 417 mcf per year and ending at 839 (averaging 700 mcf per year).[13] In some regions there is a “balance” between these two projections, such as in the Pacific Northwest where the base case removals begin below and then surpass the Burch estimates, producing nearly identical ending inventories. In the Rocky Mountains and the South, however, the Burch removals exceed the base case values in all periods, leading to lower ending inventories. In all, the Burch softwood estimates are 7 percent greater than those in the base case, and hardwoods are a notable 72 percent higher. Relative to timberland inventory, these differences are small, as the Burch softwood projections end less than one-half of one percent below the base case and the hardwoods are less by just 6 percent.

Adding disturbance and regeneration failures to the projection reduces inventories in all regions, and those most affected had the highest regeneration needs. Figure 11 shows how disturbance further contributes to different outcomes by region. The Rocky Mountain North region dominates all others in terms of both area affected and volume lost to disturbances. The Pacific Southwest and Pacific Northwest West are next in terms of significant amounts of volume lost; however, the area affected is relatively

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[13] Values are U.S. totals excluding Alaska.

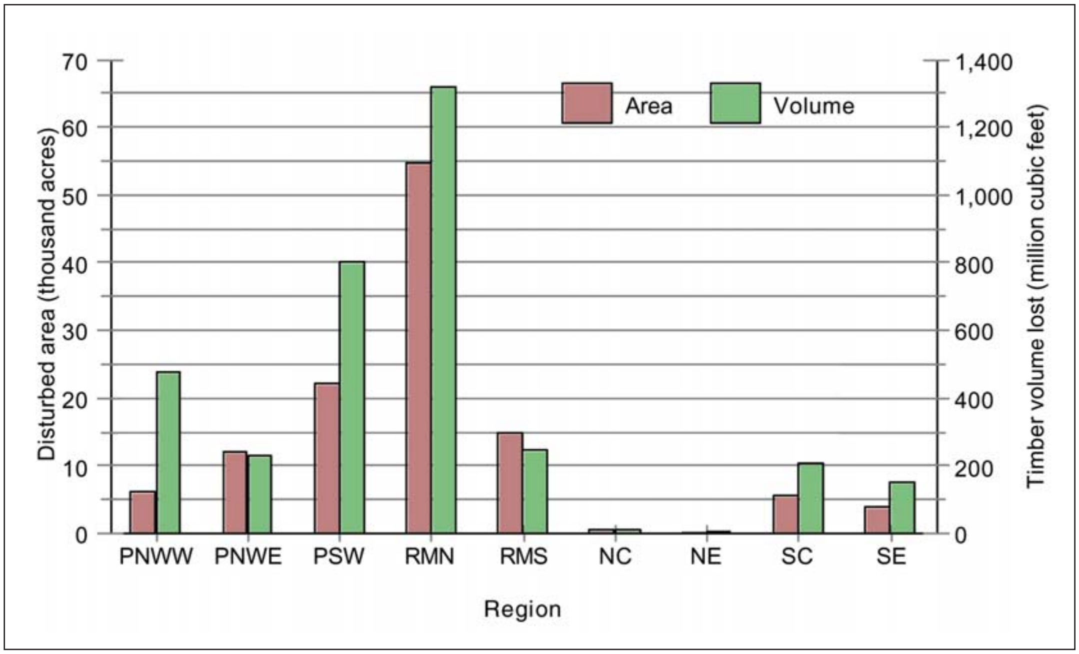

Figure 11—Projection showing area affected by disturbance and subsequent timber volume lost by region. PNWW is Pacific Northwest West, PNWE is Pacific Northwest East, PSW is Pacific Southwest, RMN is Rocky Mountain North, RMS is Rocky Mountain South, NC is North Central, NE is Northeast, SC is South Central, and SE is Southeast.

smaller, which reflects the higher average volume per acre in these regions. By 2050, the disturbances in Rocky Mountain North and Pacific Southwest reduced inventories below the base by 15 and 11 percent, respectively. In these regions, the projected (base with disturbance) softwood inventory closely matches the scenario that used the highest (1989 assessment) removal assumptions, whereas the Pacific Northwest inventory drops to match the scenario that used the 1993 assessment removals. In the remaining regions, the disturbance impacts were smaller, and the results fall slightly below the base. In all cases, however, the impacts were not enough to change the overall trend of expanding inventory volume.

As stands are projected forward in time, figures 12 through 14 show the inventory age class structure generally shifting to the right. It also can be seen that the relationship **among** age classes does not drastically change over time; the curves maintain an outline of their initial (1997) shape, shrinking in proportion to the level of disturbance and removals. Figure 12 illustrates the upper and lower bounds of the projections. All age class distributions fall between the zero cut and 1989 RPA scenarios, and like the zero cut scenario, several cross the 1989 RPA scenario with roughly 3.7 million acres near the 95-year-old age class (when the East and West are combined). The zero cut projection shifts the entire 1997 initial distribution 50 years to the right; accumulating area in the 255+ age class and producing the highest amount of old stand conditions.

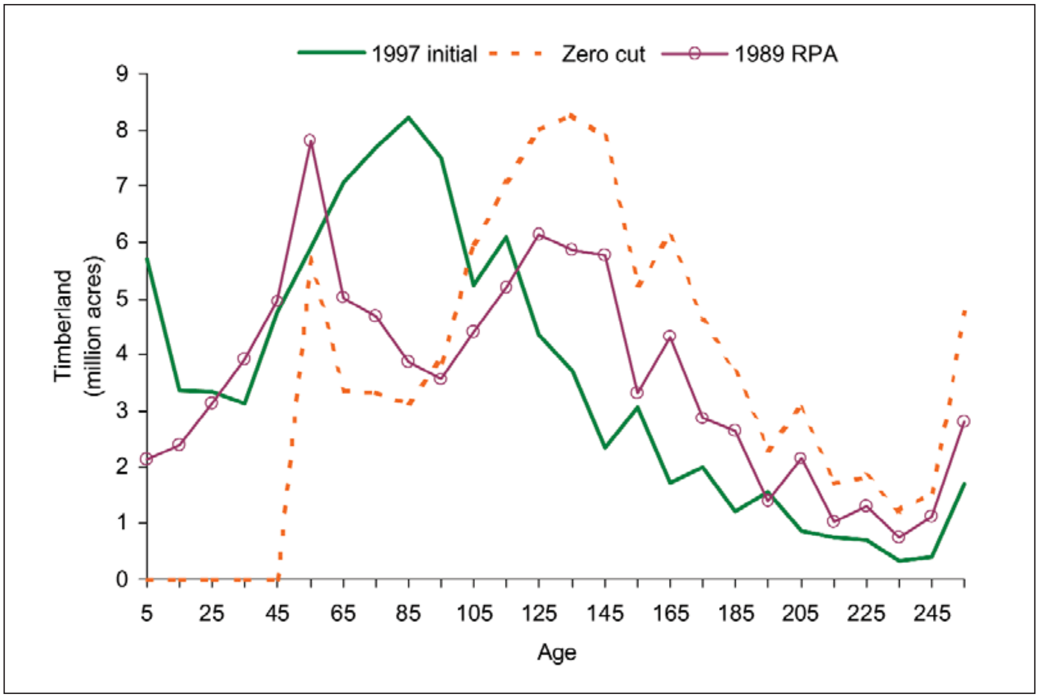

Figure 12—Timberland area by age, showing the initial (1997) distribution and projections for the lowest and highest removals.

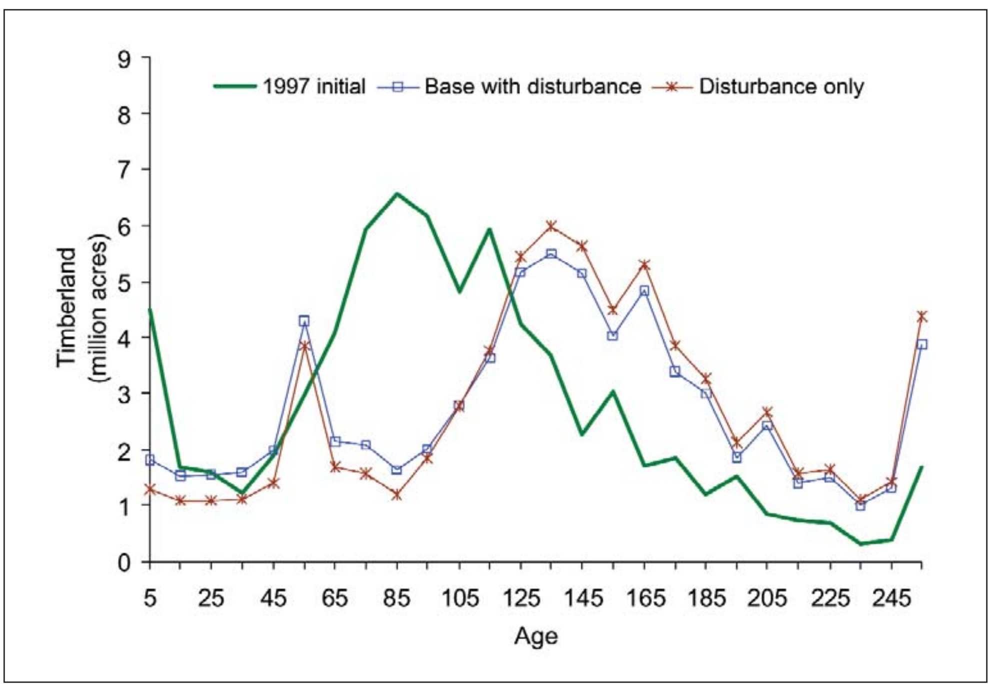

Figure 13—Western timberland area by age, showing the initial (1997) distribution and two projection scenarios that include disturbance.

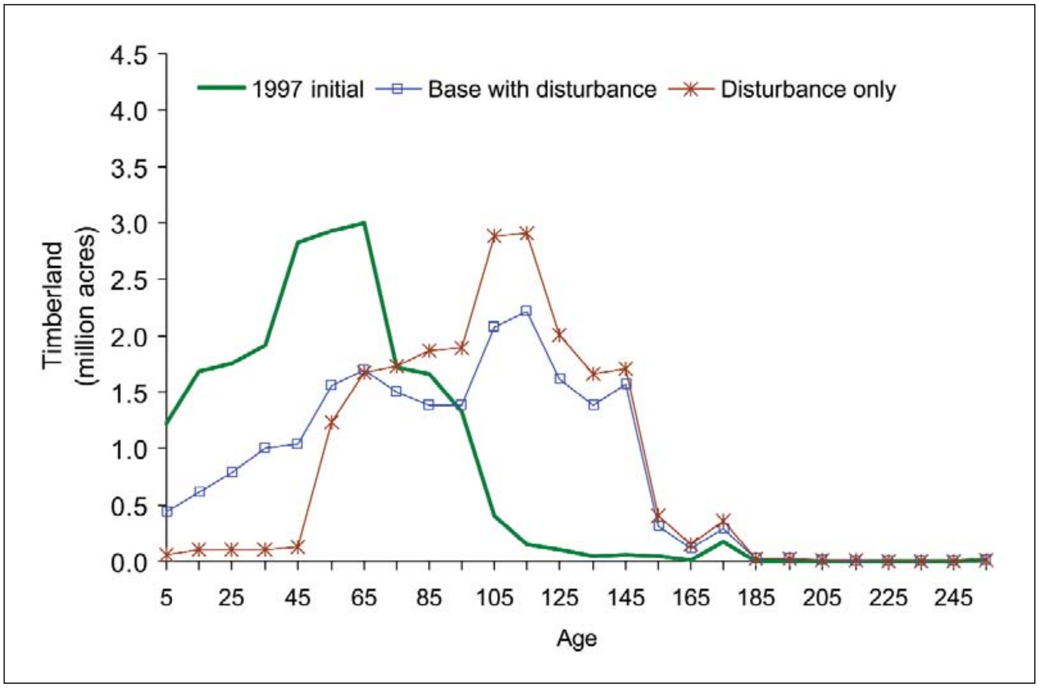

Figure 14—Eastern timberland area by age, showing the initial (1997) distribution and two projection scenarios that include disturbance.

Because we assume no harvest and no disturbance, however, there is no area to fill in the young age classes, leaving what should be considered an unrealistic gap in the young seral stages. The 1989 RPA scenario also shifts the initial distribution into older age classes, but removals flatten the distribution more than any other scenario. This relatively high level of cutting is followed by regeneration, resulting in a future with the largest area supporting younger stands.

Initially, 15 percent of the timberland is classified with stands older than 150 years. Under the base case projection, the area supporting stands older than 150 expands by 18 million acres reaching 35 percent of the timberland by 2050. Because the effects of fire, insects, and disease target older stands, adding disturbance reduces area older than 150 by about 3 million acres, dropping the share to about 32 percent. In the West, where 77 percent of NFS timberland resides, it can be seen from figure 13 how initially the bulk of the timberland, 54 percent, lies in the 80-year span between age 60 and age 140. The seral stage defined as mature sawtimber lies in the middle of this range. The base with disturbance projection pushes this bulge of acres into older age classes, but at slightly lower levels as a result of removals and disturbance. The largest projected reduction in older age classes is under the 1989 assessment scenario; the relatively high level of western removals cuts largest number of acres supporting older stands. Through regeneration and growth, this area is redistributed, showing up as stands of trees in younger age classes.

Eastern forests were initially (1997) younger, and they experienced more harvest in ages less than 100 than did western forests. Figure 14 shows that without harvest, the relatively low level of disturbance results in a significantly scant distribution of eastern

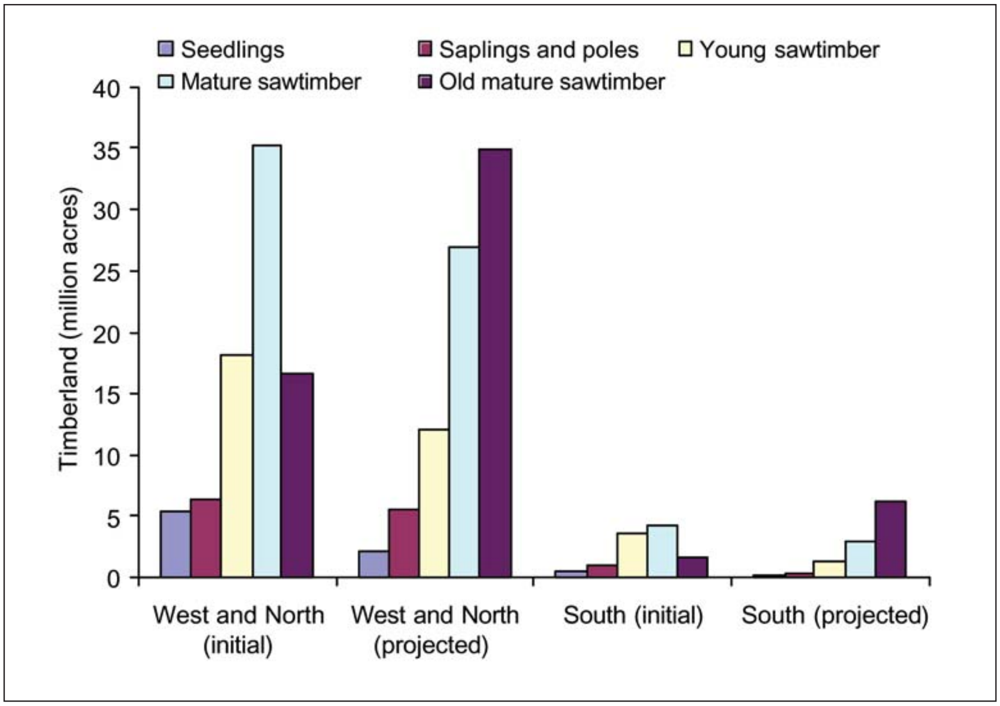

Figure 15—Timberland area distribution by product seral stage, showing initial (1997) conditions and the base case with disturbance scenario in 2050.

forests under age of 50, whereas adding harvest significantly increases the representation of younger stands. The amount of area harvested and then regenerated is influenced by the initial distribution of inventory volume by age and the level of removals, which together determine the amount of area that requires harvesting in order to supply the volume requested.

Figures 15 through 17 show the distributions of timberland in seral stages for the base case with disturbance, the disturbance-only case, and the 1989 RPA assessment scenarios. Common among them is a shift in area to oldest stage (table 3). This means that regardless of major region, an increasing share of the timberland is projected to be composed of stands represented by the old mature sawtimber seral stage. At the same time, there is a decline in area in both the young and mature sawtimber classes. In the West and North (excluding Alaska), for example, roughly 20 percent of the timberland is initially in the oldest forest class, and when all scenarios are examined, by 2050, this class represents between 35 and 52 percent of the timberland. The smallest gains in the West and North's old mature sawtimber class occur under the 1989 RPA assessment scenario (fig. 17). The higher removals target older stands and slow the growth of this class, while reductions occur in the young and mature sawtimber classes. Part of this loss of area in younger classes is from harvesting, but the majority is from acres aging and shifting to the older seral stage. It can be seen that the area harvested and moved to the seedlings and saplings and poles classes is smaller than the area reduction occurring in young and mature sawtimber classes (recall the 1989 RPA scenario does not include explicit disturbance). The pole timber stage remains constant under this scenario, bolstered in part by reforestation occurring early in the projection. The difference between this and the disturbance-only scenario in the young seral

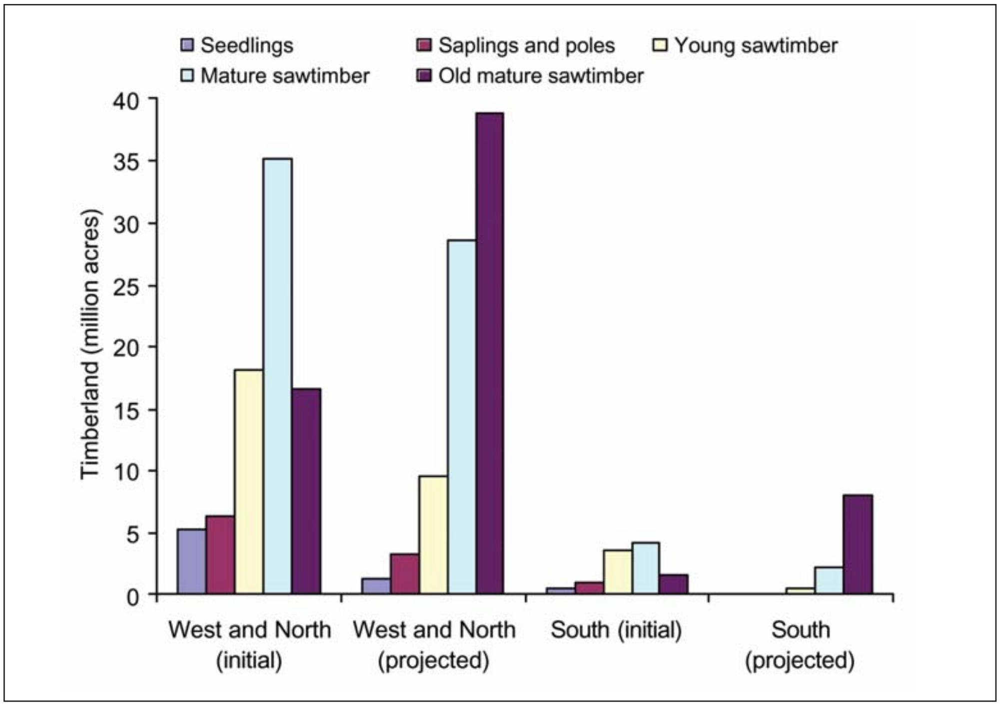

Figure 16—Timberland area distribution by product seral stage, showing initial (1997) conditions and the disturbance only scenario in 2050.

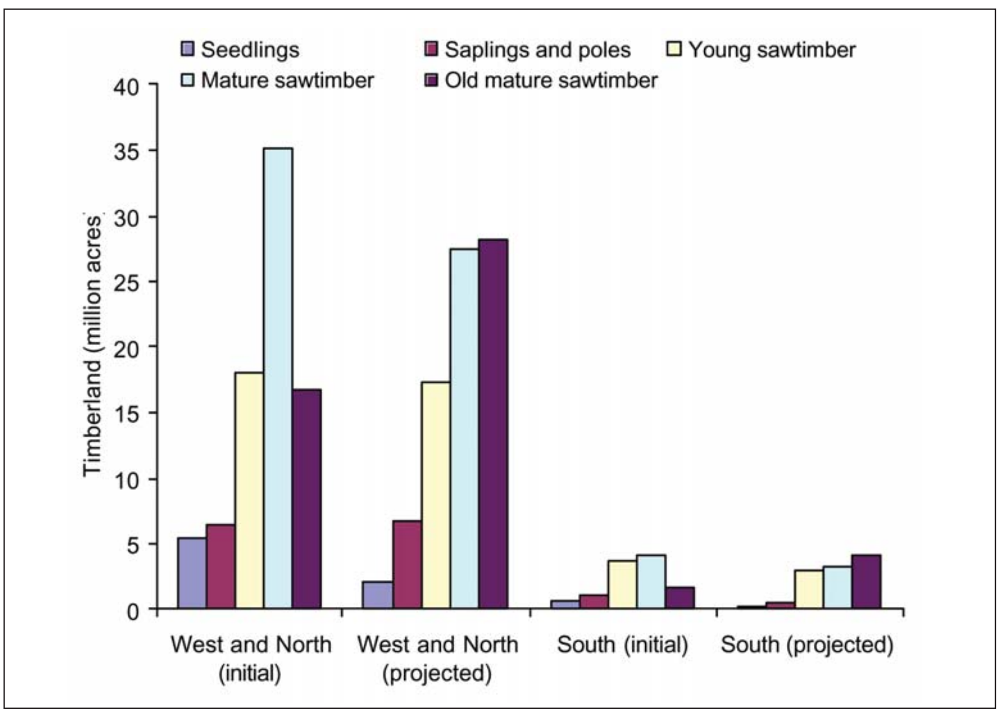

Figure 17—Timberland area distribution by product seral stage, showing initial (1997) conditions and the 1989 RPA scenario in 2050.

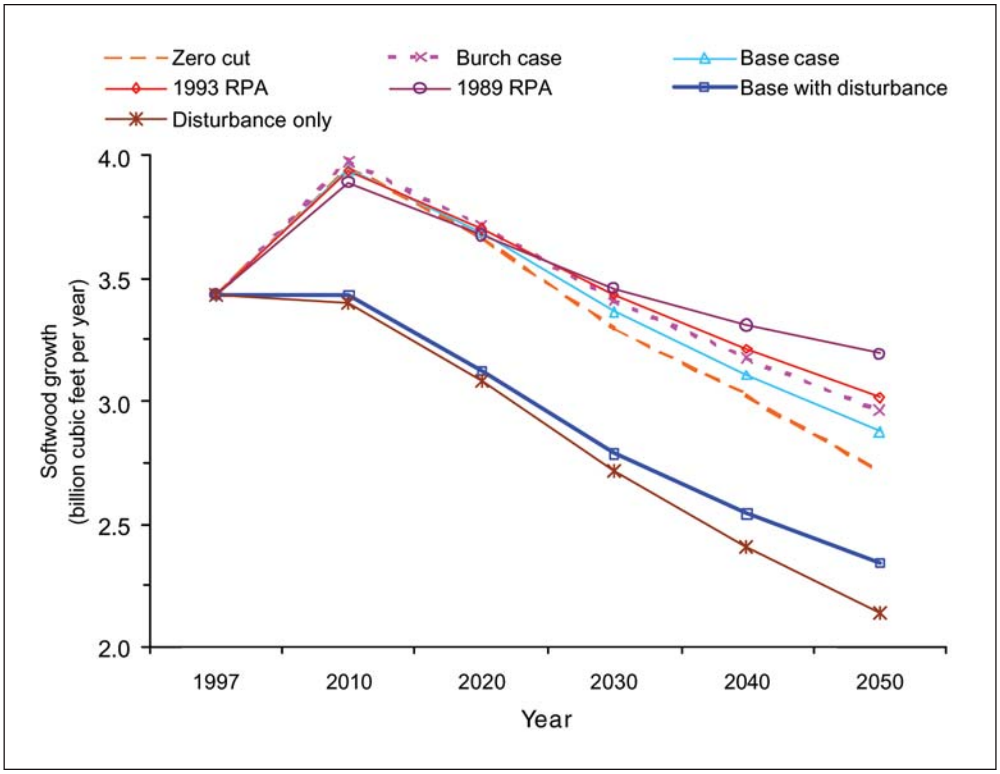

Figure 18—Projected net softwood growth by removal scenario.

stages suggests most of the decline in the old sawtimber stage is due to forests aging. Under the base case scenarios, the old mature sawtimber stage increases to represent 47 percent without, and 43 percent with disturbance. The reduction with disturbance results from the model parameters directing fire, insects, and disease to “attack” older stands.

After 2010, the trend in projected net growth is down (fig. 18), and the zero cut and disturbance-only scenarios show the steepest decline in the growth rate. This downward trend reflects an inventory with an advancing average age, as the fastest rates of growth occur before a stand reaches maturity. On average, conifers in the Western States reach their highest growth rates near age 25 in coastal states and age 55 in the Rocky Mountains; this is followed by a sharp drop and then a slow almost stable period of decline as stands age.[14] Increasing the softwood removals increases overall net growth by regenerating a steady supply of acres that advance through the young fast-growing classes. Lower removals act to create fewer numbers of young replacement stands. Perhaps less intuitive is the growth projection under disturbance where the number of young stands increases after regeneration of disturbed areas, yet growth is significantly lower. This is, in effect, an accounting issue. When harvest occurs, the volume removed from inventory is put in the category called “removals,”

[14] Source: 1997 RPA database.

and subtracted from the inventory. The volume lost in a disturbance, however, is classified as mortality, and in addition to being subtracted from inventory, the mortality volume is subtracted from gross growth to obtain net growth. Had salvage of trees killed in the disturbance scenario been assumed, it might reduce removals by substituting dead wood for growing-stock trees; furthermore, salvage of mortality would not affect the calculation of growth (see footnote 4).

Summary and Discussion

The management of national forests over the past 40 years reflects a rather dramatic shift in public values relating to uses and outputs of forests. In these scenarios, the difference between the removals projected under the 1989 and 1993 timber assessments shows how quickly expectations can change with the discovery and communication of new information—in this case, the connection between wildlife and their habitat requirements in the Pacific Northwest West region where a debate focused on protecting the northern spotted owl. Looking back to recent history—the 1960s—this region supported annual softwood removals from national forests at roughly 550 mcf, while softwood growth was just 197 mcf (USDA Forest Service 1973). What appears to be out of balance simply reflects the inventory structure at the time: a large quantity of older, slower growing high-volume stands were being replaced with young stands that had not yet reached peak performance. A study of timber resources in the Pacific Northwest, conducted in the early 1960s (USDA Forest Service 1963), reflects the thinking among forestry professionals at the time. This study examined the timber situation across all ownerships and attempted to address the issue of sustainable harvest levels by including 40-year projections. In calculating what was called "even flow," it was determined that the optimal forest age class situation would be one where trees were cut at a maximum age of 80 years on national forests and harvested at younger ages on private forests. This would lead to a stable situation where acres would be evenly distributed by age, less than age 80, across all timberlands. In this scenario, the projected timber potential (or output in terms of removals) for the Pacific Northwest West national forests in 2000 was roughly 655 mcf per year, which would have composed 30 percent of the region's total harvest. By 2000 it was expected that national forest inventories would be reduced by 30 percent from 1960, and it was recognized that there would be "a shift in the regional harvest toward a larger percentage of young-growth timber as the liquidation of old growth progresses." By 1989, many policies[15] affecting outputs of timber from public lands had changed, resulting in a drop in the emphasis on removals. Projections for the year 2000 were for removals of 460 mcf. By 1993 the projection fell to 114 mcf, and today it is estimated the national forest removals in the Pacific Northwest West were roughly 39 mcf in 2000. Meanwhile, in the 1960s, private timberlands in this region were projected to produce 1.2 billion cubic feet per year in 2000, whereas the current assessment estimated 1.6 billion cubic feet in 2000. Improvements in technology likely contribute to the ability to

[15] Policies regarding harvest from public land were shaped by changing public attitudes regarding the environment that were reflected by a series of laws passed by Congress, including the 1964 Multiple Use and Sustainable Yield Act, the 1969 National Environmental Management Act, the 1973 Endangered Species Act, the Renewable Resource Planning Act of 1974, the National Forest Management Act of 1976, and the Forest and Rangeland Renewable Resources Research Act of 1978.

support 33 percent more private removals; the intensification of stand management leading to rotations at younger ages, and the improvements in processing technology increase the utility of harvesting smaller logs. The management of public forests reflects a changing set of values, and national forest timber harvested in 2000 was roughly 2.2 percent of the region's total harvest.

The projections made for NFS timberlands today are consistent in both a modeling and data perspective with projections made for private timberlands in the 2000 RPA timber assessment. This is the first use of the new NFS Western plot-level inventory data for regional projections. The results show a range of outcomes dependent on the levels of removals and the amount of disturbance. In all cases, they show a future in which removals and disturbance are exceeded by growth resulting in a significant increase in the inventory volume on national forest timberland. The smallest increase occurs under the assumptions incorporated into the 1989 assessment scenario, where the total softwood inventory gains 43 percent and the hardwood volume increases by 56 percent (excluding Alaska). This scenario did not incorporate explicit disturbances; however, if we apply the same reduction from disturbance that occurred in the base scenario, the trend would still be upward, as the ending volume would be reduced by roughly 10 percent. The highest inventory gains, 83 percent softwood and 94 percent hardwood, occur when no harvesting and no major disturbances are modeled. This "upper-bound" is unrealistic because, at the very least, forests evolved with major disturbances, and it is safe to assume disturbances will continue. The volumes projected under the three remaining scenarios fall closer to the middle, including two versions that explicitly project stand-replacing disturbance events.

When compared to private lands, national forests have a greater proportion of stands dispersed among the full range of age classes. This age class distribution implies that national forests likely support a broader range of habitats for plant and animal species. In 1997, about 39 percent of the national forest timberland had stands more than 100 years old, while this was true for just 5 percent of private timberland. The RPA projection (Haynes, in press) suggests this will increase to 15 percent on private lands, and the base projection (with disturbance) shows an increase on national forests to 65 percent of timberland in age classes over 100 years. Although this might appear to be disproportionate, by 2050 the combined projections show 110 million acres age 100 and greater, and about half (55 percent) are in national forests. Consequently, this means a future with less area in the younger seral stages. Perhaps in addition to fiber production, the role of private timberlands will be to fill this niche and provide the ecosystem services associated with younger stands. Meanwhile, the public timberlands on national forests will continue to play multiple roles in meeting the needs of an increasingly diverse society.

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Metric Equivalents

When you know:	Multiply by:	To find:
Acres	0.4047	Hectares
Cubic feet	0.02832	Cubic meters
Cubic feet per acre	0.06997	Cubic meters per hectare

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Appendix

Table 7—National forest assessment (RPA) regions

RPA region	Region name	States
0	Pacific Northwest West	Western Oregon, western Washington
1	Pacific Northwest East	Eastern Oregon, eastern Washington
2	Pacific Southwest	California, Hawaii
3	Rocky Mountain North	Idaho, Montana
4	Rocky Mountain South	Arizona, Colorado, Nevada, New Mexico, western South Dakota, Utah,Wyoming
5	North Central—Plains States	Illinois, Indiana, Iowa, Kansas, Missouri, Nebraska, Ohio
6	North Central—Lake States	Michigan, Minnesota, Wisconsin, North Dakota, eastern South Dakota
7	Northeast	Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia
8	South Central	Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas
9	Southeast	Florida, Georgia, North Carolina, South Carolina, Virginia
10	Alaska	Alaska (not projected with ATLAS)

Table 8—Forest types projected for national forests by RPA regions

RPA region	Region name	States
0	Pacific Northwest West	Douglas-fir, western hemlock, fir and spruce, pine, red alder, hardwood mix, nonstocked
1	Pacific Northwest East	Ponderosa pine, Douglas-fir and larch, true fir, lodgepole pine, hardwood, nonstocked
2	Pacific Southwest	True fir, Douglas-fir, ponderosa pine, mixed conifer, pinyon/juniper, chaparral, redwood, hardwood, nonstocked
3	Rocky Mountain—North	Douglas-fir, fir and spruce, lodgepole pine, ponderosa pine, hardwood, high elevation, nonstocked
4	Rocky Mountain—South	Douglas-fir, fir and spruce, lodgepole pine, ponderosa pine, hardwood, pinyon/juniper, high-elevation softwoods, nonstocked
5	North Central—Plains States	Oak and hickory, pines, oak-pine, lowland hardwood, maple and beech, nonstocked
6	North Central—Lake States	Jack pine, red pine, white pine, spruce and balsam fir, swamp conifer, oak and hickory, lowland hardwood, maple and beech, aspen and birch, nonstocked
7	Northeast	White/red/jack pine, spruce and balsam fir, loblolly/shortleaf/oak/gum/cypress, oak-pine, oak and hickory, elm/ash/red maple, maple/beech/birch, aspen/birch, nonstocked
8	South Central	Planted pine, natural pine, oak-pine, upland hardwood, lowland hardwood, nonstocked
9	Southeast	Planted pine, natural pine, oak-pine, upland hardwood, lowland hardwood, nonstocked
10	Alaska	Western hemlock, hemlock-spruce, spruce (not modeled)

Table 9—Yield tables for the Pacific Northwest West region by forest type

Age class	Douglas-fir	Western hemlock	Fir and spruce	Pine	Red alder	Hardwood mix
			Cubic feet per acre			
5	0	0	0	0	0	0
15	535	482	117	405	708	5
25	2,985	2,631	890	1,873	3,282	486
35	5,600	5,013	2,080	3,099	5,442	1,632
45	7,927	7,385	3,412	4,173	7,342	3,089
55	9,981	9,699	4,772	5,135	9,050	4,704
65	11,804	11,935	6,103	6,008	10,605	6,393
75	13,432	14,086	7,371	6,807	12,034	8,103
85	14,893	16,146	8,560	7,542	13,355	9,802
95	16,213	18,113	9,661	8,223	14,582	11,467
105	17,411	19,983	10,670	8,854	15,725	13,083
115	18,503	21,757	11,588	9,441	16,792	14,640
125	19,503	23,432	12,421	9,988	17,791	16,133
135	20,422	25,008	13,174	10,499	18,727	17,558
145	21,272	26,484	13,855	10,975	19,605	18,913
155	22,060	27,860	14,474	11,420	20,429	20,200
165	22,794	29,135	15,042	11,836	21,203	20,200
175	23,482	30,310	15,568	12,224	21,930	20,200
185	24,128	31,384	16,066	12,587	22,613	20,200
195	24,740	32,356	16,548	12,925	23,254	20,200
205	25,320	33,227	17,027	13,240	23,855	20,200
215	25,875	33,997	17,517	13,532	24,419	20,200
225	26,408	34,664	18,032	13,804	24,947	20,200
235	26,922	35,230	18,585	14,056	25,440	20,200
245	27,421	35,694	19,191	14,289	25,901	20,200
255	27,909	36,055	19,865	14,503	26,331	20,200

Table 10—Yield tables for the Pacific Northwest East region by forest type

Age class	Ponderosa pine	Douglas-fir and larch	True fir	Lodgepole pine	Hardwood
			Cubic feet per acre		
5	0	0	0	0	0
15	59	54	0	95	32
25	309	682	217	583	261
35	583	1,701	745	1,168	585
45	878	2,639	1,392	1,722	891
55	1,190	3,456	2,063	2,234	1,166
65	1,515	4,157	2,711	2,706	1,413
75	1,848	4,755	3,308	3,142	1,631
85	2,187	5,264	3,840	3,544	1,825
95	2,527	5,697	4,302	3,916	1,996
105	2,864	6,065	4,691	4,261	2,145
115	3,195	6,379	5,010	4,580	2,275
125	3,515	6,648	5,264	4,876	2,388
135	3,822	6,881	5,459	5,150	2,483
145	4,110	7,085	5,602	5,403	2,563
155	4,376	7,269	5,704	5,637	2,628
165	4,616	7,438	5,773	5,854	2,680
175	4,826	7,599	5,822	6,053	2,718
185	5,003	7,758	5,860	6,237	2,744
195	5,142	7,922	5,901	6,405	2,758
205	5,239	8,095	5,956	6,559	2,763
215	5,292	8,283	6,037	6,699	2,763
225	5,306	8,491	6,159	6,825	2,763
235	5,306	8,725	6,333	6,939	2,763
245	5,306	8,988	6,574	7,041	2,763
255	5,306	9,285	6,895	7,132	2,763

Table 11—Yield tables for the Pacific Southwest region by forest type

Age class	Pinyon juniper	True fir	Hardwood	Douglas-fir and redwood	Ponderosa pine	Mixed conifer
			Cubic feet per acre			
5	0	0	0	0	0	0
15	1	28	0	58	5	29
25	11	196	15	397	66	159
35	26	463	370	832	205	349
45	47	840	1,090	1,250	415	636
55	73	1,343	1,826	1,660	689	1,028
65	103	1,954	2,493	2,076	1,024	1,523
75	137	2,652	3,072	2,510	1,411	2,114
85	173	3,419	3,564	2,970	1,845	2,793
95	211	4,239	3,979	3,461	2,321	3,548
105	251	5,099	4,328	3,987	2,832	4,368
115	291	5,989	4,620	4,552	3,372	5,240
125	332	6,899	4,868	5,156	3,935	6,152
135	372	7,822	5,082	5,801	4,516	7,090
145	410	8,750	5,269	6,487	5,107	8,041
155	447	9,678	5,440	7,214	5,703	8,990
165	481	10,600	5,600	7,980	6,299	9,924
175	511	11,511	5,758	8,785	6,887	10,828
185	537	12,408	5,919	9,627	7,463	11,687
195	558	13,286	6,089	10,505	8,020	12,488
205	574	14,143	6,273	11,417	8,551	13,216
215	584	14,974	6,478	12,360	9,052	13,856
225	587	15,778	6,706	13,334	9,515	14,394
235	587	16,551	6,961	14,335	9,936	14,814
245	587	17,291	7,249	15,361	10,307	15,102
255	587	17,997	7,572	16,410	10,624	15,242

Table 12—Yield tables for the Rocky Mountain North region by forest type

Age class	Douglas-fir	Ponderosa pine	Fir-spruce	Lodgepole pine	Hardwood	High-elevation softwoods
			Cubic feet per acre			
5	0	0	0	0	0	0
15	16	19	0	3	20	27
25	281	266	260	227	132	153
35	816	740	880	737	309	312
45	1,442	1,278	1,626	1,348	589	499
55	2,085	1,816	2,390	1,983	960	713
65	2,705	2,318	3,118	2,603	1,334	951
75	3,283	2,769	3,782	3,189	1,660	1,210
85	3,806	3,159	4,365	3,730	1,915	1,486
95	4,268	3,483	4,862	4,220	2,093	1,778
105	4,667	3,742	5,271	4,658	2,201	2,082
115	5,003	3,938	5,596	5,048	2,253	2,395
125	5,280	4,075	5,842	5,392	2,272	2,715
135	5,500	4,158	6,018	5,697	2,276	3,039
145	5,669	4,193	6,133	5,969	2,276	3,363
155	5,794	4,199	6,199	6,215	2,276	3,686
165	5,879	4,199	6,227	6,444	2,276	4,004
175	5,934	4,199	6,233	6,665	2,276	4,315
185	5,964	4,199	6,233	6,888	2,276	4,615
195	5,979	4,199	6,233	7,122	2,276	4,902
205	5,987	4,199	6,233	7,376	2,276	5,172
215	5,996	4,199	6,233	7,663	2,276	5,424
225	6,015	4,199	6,233	7,992	2,276	5,654
235	6,053	4,199	6,233	8,374	2,276	5,860
245	6,119	4,199	6,233	8,820	2,276	6,038
255	6,223	4,199	6,233	9,342	2,276	6,185

Table 13—Yield tables for the Rocky Mountain South region by forest type

Age class	Douglas-fir	Ponderosa pine	Fir-spruce	Lodgepole pine	Hardwood	Pinyon juniper	High-elevation softwoods
				Cubic feet per acre			
5	0	0	0	0	0	0	0
15	23	0	0	0	0	3	9
25	219	63	122	71	90	26	61
35	559	231	396	262	324	62	138
45	946	460	708	529	643	108	230
55	1,342	719	1,028	836	1,010	159	333
65	1,726	990	1,345	1,160	1,402	213	444
75	2,088	1,263	1,654	1,488	1,808	270	561
85	2,422	1,532	1,951	1,810	2,215	328	684
95	2,726	1,793	2,235	2,120	2,617	386	810
105	2,999	2,043	2,504	2,410	3,008	444	940
115	3,244	2,280	2,758	2,677	3,384	500	1,073
125	3,463	2,503	2,995	2,917	3,741	554	1,208
135	3,658	2,713	3,216	3,127	4,075	606	1,346
145	3,833	2,909	3,420	3,305	4,385	654	1,485
155	3,992	3,093	3,607	3,448	4,667	699	1,626
165	4,140	3,264	3,776	3,553	4,920	739	1,768
175	4,282	3,424	3,928	3,621	5,142	774	1,911
185	4,422	3,575	4,062	3,648	5,332	804	2,055
195	4,567	3,717	4,178	3,652	5,489	829	2,200
205	4,721	3,853	4,276	3,652	5,610	846	2,345
215	4,890	3,983	4,356	3,652	5,695	859	2,491
225	5,080	4,110	4,417	3,652	5,744	861	2,637
235	5,296	4,236	4,460	3,652	5,759	861	2,783
245	5,545	4,362	4,485	3,652	5,759	861	2,929
255	5,833	4,490	4,493	3,652	5,759	861	3,076

Table 14—Yield tables for the North Central Plains States region by forest type

Age class	Pine	Oak-pine	Oak and hickory	Lowland hardwood	Maple and beech
			Cubic feet per acre		
5	0	0	0	0	0
15	116	65	30	0	13
25	575	406	186	83	117
35	1,000	828	391	312	306
45	1,366	1,239	615	644	546
55	1,682	1,618	844	1,043	821
65	1,956	1,959	1,070	1,488	1,123
75	2,192	2,259	1,289	1,964	1,443
85	2,397	2,515	1,497	2,456	1,778
95	2,574	2,727	1,691	2,956	2,123
105	2,724	2,893	1,869	3,454	2,474
115	2,851	3,014	2,030	3,941	2,821
125	2,958	3,088	2,171	4,410	3,151
135	3,044	3,115	2,292	4,855	3,466
145	3,112	3,117	2,392	5,236	3,766
155	3,163	3,117	2,471	5,516	4,041
165	3,199	3,117	2,526	5,696	4,281
175	3,219	3,117	2,559	5,761	4,466
185	3,226	3,117	2,569	5,761	4,566
195	3,226	3,117	2,569	5,761	4,591
205	3,226	3,117	2,569	5,761	4,591
215	3,226	3,117	2,569	5,761	4,591
225	3,226	3,117	2,569	5,761	4,591
235	3,226	3,117	2,569	5,761	4,591
245	3,226	3,117	2,569	5,761	4,591
255	3,226	3,117	2,569	5,761	4,591

Table 15—Yield tables for the North Central Lake States region by forest type

Age class	Jack pine	Red pine	White pine	Spruce and balsam fir	Swamp conifer	Oak and hickory	Lowland hardwood	Maple and beech	Aspen and birch
					Cubic feet per acre				
5	0	0	0	0	0	0	0	0	0
15	25	94	182	43	25	58	35	62	42
25	179	688	871	332	156	313	189	351	307
35	401	1,496	1,488	730	315	608	360	688	674
45	641	2,271	2,049	1,103	468	928	535	1,036	1,041
55	890	2,988	2,567	1,439	611	1,267	712	1,385	1,388
65	1,144	3,646	3,057	1,738	745	1,620	890	1,733	1,708
75	1,400	4,250	3,532	2,003	870	1,986	1,070	2,076	1,996
85	1,657	4,804	4,007	2,237	987	2,361	1,250	2,414	2,251
95	1,908	5,312	4,496	2,442	1,097	2,745	1,431	2,743	2,472
105	2,142	5,777	4,976	2,622	1,200	3,133	1,613	3,064	2,658
115	2,325	6,203	5,421	2,778	1,297	3,521	1,798	3,373	2,807
125	2,465	6,593	5,836	2,912	1,389	3,895	1,990	3,671	2,920
135	2,596	6,950	6,221	3,025	1,475	4,217	2,188	3,956	2,996
145	2,716	7,274	6,576	3,119	1,556	4,389	2,385	4,227	3,035
155	2,827	7,569	6,901	3,195	1,633	4,420	2,583	4,482	3,045
165	2,928	7,837	7,196	3,254	1,705	4,420	2,770	4,720	3,045
175	3,018	8,078	7,461	3,297	1,773	4,420	2,938	4,940	3,045
185	3,099	8,294	7,696	3,325	1,837	4,420	3,085	5141	3,045
195	3,169	8,486	7,901	3,339	1,897	4,420	3,213	5,322	3,045
205	3,230	8,655	8,076	3,342	1,954	4,420	3,320	5,482	3,045
215	3,281	8,803	8,221	3,342	2,008	4,420	3,408	5,619	3,045
225	3,321	8,931	8,336	3,342	2,058	4,420	3,475	5,732	3,045
235	3,352	9,039	8,421	3,342	2,105	4,420	3,523	5,820	3,045
245	3,372	9,127	8,476	3,342	2,150	4,420	3,550	5,882	3,045
255	3,380	9,198	8,496	3,342	2,191	4,420	3,559	5,917	3,045

Table 16—Yield tables for the Northeast region by forest type

Age class	Jack/red/ white pine	Spruce and balsam fir	Loblolly/ shortleaf/ oak/gum/ cypress	Oak-pine	Oak and hickory	Elm/ash/ red maple	Maple/ beech/ birch	Aspen/ birch
				Cubic feet per acre				
5	0	0	0	0	0	0	0	0
15	429	164	1,009	522	779	436	400	184
2 5	777	416	1,773	1,013	1,368	880	830	483
35	1,113	738	2,443	1,473	1,934	1,388	1,280	835
45	1,438	1,099	3,021	1,902	2,477	1,894	1,702	1,210
55	1,751	1,466	3,505	2,300	2,996	2,367	2,095	1,607
65	2,034	1,807	3,896	2,668	3,492	2,806	2,460	2,025
75	2,300	2,133	4,193	3,004	3,965	3,211	2,796	2,466
85	2,550	2,443	,4398	3,309	4,415	3,582	3,103	2,929
95	2,783	2,738	4,509	3,584	4,842	3,820	3,382	3,414
105	3,001	3,017	4,528	3,828	5,246	4,224	3,632	3,921
115	3,202	3,281	4,528	4,040	5,626	4,494	3,854	4,450
125	3,389	3,532	4,528	4,222	5,983	4,731	4,047	5,001
135	3,561	3,768	4,528	4,373	6,317	4,34	4,211	5,574
145	3,718	3,990	4,528	4,493	6,628	5,103	4,347	6,170
155	3,861	4,197	4,528	4,581	6,916	5,238	4,455	6,787
165	4,030	4,436	4,528	4,639	7,180	5,340	4,534	7,427
175	4,189	4,666	4,528	4,667	7,421	5,408	4,584	8,089

Table 17—Yield tables for the South Central and Southeast regions by forest type

Age class	Planted pine	Natural pine	Oak-pine	Upland hardwood	Lowland hardwood
			Cubic feet per acre		
5	0	0	0	0	0
10	331	273	195	167	140
15	1,167	525	397	303	284
20	2,067	863	628	483	467
25	2,782	1,222	848	666	649
30	3,211	1,554	1,104	860	830
35	3,360	1,875	1,384	1,091	1,049
40	3,439	2,177	1,675	1,348	1,318
45	3,517	2,462	1,950	1,630	1,582
50	3,595	2,736	2,202	1,901	1,830
55	3,675	2,978	2,450	2,164	2,091
60	3,755	3,200	2,710	2,414	2,374
65	3,835	3,407	2,923	2,652	2,664
70	3,915	3,614	3,127	2,880	2,940
75	3,995	3,782	3,352	3,082	3,180
80	4,075	3,960	3,539	3,278	3,400
85	4,155	4,138	3,707	3,465	3,677
90	4,235	4,281	3,891	3,632	3,986

Table 18—Softwood removals, inventory, and growth on national forests, 1991 and 1997 with projections to 2050 under the base case scenario without disturbance

Region	1991	1997	Projections 2010	2020	2030	2040	2050
			Million cubic feet				
Northeast:							
Removals	5	5	5	4	5	4	5
Inventory	723	782	1,044	1,118	1,184	1,243	1,297
Net annual growth	17	14	12	11	11	10	10
North Central:							
Removals	48	24.6	24.9	26.3	27.0	27.8	28.2
Inventory	3,216	3,646	4,560	5,046	5,451	5,766	6,058
Net annual growth	84	94.9	75.6	70.1	59.5	57.2	56.7
Southeast:							
Removals	59	47.3	28.3	34.9	35.5	35.6	35.5
Inventory	2,826	2,991	4,116	4,627	4,879	5,030	5,147
Net annual growth	50	57.2	99.3	70.3	54.5	48.6	46.5
South Central:							
Removals	169	139.4	77.2	93.0	93.9	93.4	93.0
Inventory	6,013	6,396	7,501	8,054	8,383	8,672	8,908
Net annual growth	174	192	155.0	132.4	124.5	120.6	113.6
Rocky Mountains:							
Removals	389	130	141.9	172.2	183.3	193.3	199.5
Inventory	71,657	84,925	103,127	117,191	129,510	139,863	148,486
Net annual growth	1,285	1,272.9	1,597.1	1,465.0	1,273.1	1,101.4	954.8
Pacific Southwest:							
Removals	314	95.6	107.5	132.0	138.7	145.2	148.1
Inventory	31,448	29,539	36,765	42,055	47,197	52,244	57,137
Net annual growth	463	616.2	642.0	648.2	648.3	638.5	628.2
Pacific Northwest West:							
Removals	266	65.8	48.7	62.6	74.4	86.2	93.5
Inventory	33,621	51,399	62,799	71,103	78,727	85,640	92,011
Net annual growth	320	777.8	898.3	848.4	781.9	739.9	692.1
Pacific Northwest East:							
Removals	330	71.6	68.3	86.8	103.3	119.8	130.4
Inventory	17,338	23,915	28,039	30,992	33,517	35,642	37,418
Net annual growth	269	319.8	376.8	351.6	327.0	306.0	288.1
Alaska:							
Removals	99	50.5	29.3	29.3	29.3	29.3	29.3
Inventory	18,733	18,733	19,290	19,847	20,404	20,961	21,518
Net annual growth	85	85	85	85	85	85	85
United States:							
Removals	1,679	629.3	530.6	641.4	690.0	735.0	762.2
Inventory	185,575	222,326	267,241	300,033	329,252	355,061	377,980
Net annual growth	2,747	3,430	3,941.3	3,682.1	3,364.4	3,107.3	2,874.5

Table 19—Hardwood removals, inventory, and growth on national forests, 1991 and 1997 with projections to 2050 under the base case scenario without disturbance

			Projections				
Region	**1991**	**1997**	**2010**	**2020**	**2030**	**2040**	**2050**
				Million cubic feet			
Northeast:							
Removals	22	16.5	8.2	9.7	10.1	10.8	10.5
Inventory	3,711	3,696	4,237	4,743	5,203	5,629	6,015
Net annual growth	88	68.5	60.3	56.6	54.0	50.5	46.6
North Central:							
Removals	61	64.1	44.0	44.9	45.7	46.6	46.7
Inventory	5,228	6,282	7,932	8,925	9,609	10,200	10,741
Net annual growth	123	139	164.5	136.6	112	104.2	100.3
Southeast:							
Removals	13	51.1	8.5	10.3	10.1	9.9	9.8
Inventory	5,565	5,773	7,397	8,213	8,743	9,094	9,338
Net annual growth	114	104.6	110.1	77.7	52.9	38.9	31.0
South Central:							
Removals	36	55.5	23.7	29.0	29.5	29.8	30.1
Inventory	4,959	5,249	7,073	8,213	9,152	9,867	10,304
Net annual growth	147	144.3	146.9	134.4	114.7	87.6	63.5
West:							
Removals	54	11.1	6.3	7.4	8.3	8.4	9.0
Inventory	6,178	8,613	10,688	12,401	13,809	15,131	16,446
Net annual growth	71	213.6	189.0	152.0	140.3	140.9	138.3
Alaska:							
Removals	N/A	0.4	0.3	0.3	0.3	0.3	0.3
Inventory	N/A	176	214	252	290	328	366
Net annual growth	N/A	4.1	4.1	4.1	4.1	4.1	4.1
United States:							
Removals	186	198.7	92.5	98.9	102	105	105.7
Inventory	25,641	29,789	37,541	42,747	46,806	50,249	53,210
Net annual growth	543	674.1	674.9	561.4	478.0	426.2	383.8

N/A = not available.

Table 20—Softwood removals, inventory, and growth on national forests, 1991 and 1997 with projections to 2050 under the Burch scenario

			Projections				
Region	**1991**	**1997**	**2010**	**2020**	**2030**	**2040**	**2050**
				Million cubic feet			
Northeast:							
Removals	5	5	2	2	2	2	2
Inventory	723	782	1,076	1,174	1,260	1,339	1,411
Net annual growth	17	14	12	11	10	9	9
North Central:							
Removals	48	25	24	25	25	25	25
Inventory	3,216	3,646	4,285	4,755	5,184	5,539	5,882
Net annual growth	84	9,439	72	70	61	59	58
Southeast:							
Removals	59	47	45	46	46	46	46
Inventory	2,826	2,991	3,875	4,285	4,496	4,627	4,733
Net annual growth	50	57	101	75	62	58	56
South Central:							
Removals	169	139	108	107	107	107	107
inventory	6,013	6,396	7,097	7,507	7,794	8,069	8,312
Net annual growth	174	192	161	140	135	134	129
Rocky Mountains:							
Removals	389	130	298	299	299	299	299
Inventory	71,657	84,925	100,725	113,177	124,214	133,555	
Net annual growth	1,285	1,273	1,582	1,455	1,280	1,123	992
Pacific Southwest:							
Removals	314	96	48	48	47	48	47
Inventory	31,448	29,539	37,279	43,289	49,382	55,484	61,494
Net annual growth	463	616	646	655	660	652	641
Pacific Northwest West:							
Removals	266	66	55	55	55	55	55
Inventory	33,621	51,399	62,611	70,885	78,608	85,736	92,416
Net annual growth	320	778	940	873	792	753	709
Pacific Northwest East:							
Removals	330	72	66	66	66	66	66
Inventory	17,338	23,915	27,924	30,958	33,747	36,299	38,631
Net annual growth	269	320	376	352	328	305	284
Alaska:							
Removals	99	51	29	29	29	29	29
Inventory	18,733	18,733	19,290	19,847	20,404	20,961	21,518
Net annual growth	85	85	85	85	85	85	85
United States:							
Removals	1,679	629	675	675	676	676	676
Inventory	185,575	222,326	264,162	295,877	325,089	351,609	375,804
Net annual growth	2,747	12,774	3,975	3,716	3,412	3,178	2,964

Table 21—Hardwood removals, inventory, and growth on national forests, 1991 and 1997 with projections to 2050 under the Burch scenario

Region	1991	1997	Projections 2010	2020	2030	2040	2050
			Million cubic feet				
Northeast:							
Removals	22	17	2	2	2	2	2
Inventory	3,711	3,696	4,282	4,819	5,318	5,785	6,209
Net annual growth	88	69	60	56	53	49	45
North Central:							
Removals	61	64	62	62	62	61	61
Inventory	5,228	6,282	7,671	8,465	8,971	9,415	9,826
Net annual growth	123	136	152	114	107	103	102
Southeast:							
Removals	13	51	21	21	20	20	20
Inventory	5,565	5,773	7,237	7,964	8,436	8,748	8,969
Net annual growth	114	105	111	81	58	46	39
South Central:							
Removals	36	56	59	60	60	60	61
Inventory	4,959	5,249	6,568	7,413	8,135	8,711	9,094
Net annual growth	147	144	149	140	127	108	92
West:							
Removals	54	11	24	24	24	23	24
Inventory	6,178	8,613	10,467	11,985	13,202	14,345	15,503
Net annual growth	71	214	187	149	137	140	138
Alaska:							
Removals	N/A	0	0	0	0	0	0
Inventory	N/A	176	214	252	290	328	366
Net annual growth	N/A	4.1	4	4	4	4	4
United States:							
Removals	186	199	168	168	168	167	168
Inventory	25,641	29,789	36,439	40,898	44,352	47,332	49,967
Net annual growth	543	671	663	544	486	449	421

N/A = not available.

Table 22—Softwood removals, inventory, and growth on national forests, 1991 and 1997 with projections to 2050 under the 1989 RPA scenario

Region	1991	1997	Projections 2010	2020	2030	2040	2050
			Million cubic feet				
Northeast:							
Removals	5	5	8	8	9	9	8
Inventory	723	782	1,012	1,054	1,086	1,112	1,138
Net annual growth	17	14	12	12	11	11	10
North Central:							
Removals	48	25	41	44	48	48	48
Inventory	3,216	3,646	4,331	4,624	4,829	4,950	5,080
Net annual growth	84	95	73	69	60	60	62
Southeast:							
Removals	59	47	49	51	53	53	53
Inventory	2,826	2,991	3,830	4,209	4,382	4,474	4,548
Net annual growth	50	57	102	76	64	61	60
South Central:							
Removals	169	139	161	166	172	172	172
Inventory	6,013	6,396	6,545	6,542	6,457	6,413	6,396
Net annual growth	174	192	171	159	164	170	170
Rocky Mountains:							
Removals	389	130	571	595	618	618	618
Inventory	71,657	84,925	97,221	106,681	114,617	120,963	126,141
Net annual growth	1,285	1,273	1,560	1,440	1,290	1,164	1,069
Pacific Southwest:							
Removals	314	96	257	261	264	265	264
Inventory	31,448	29,539	34,478	38,091	41,627	45,086	48,461
Net annual growth	463	616	621	617	613	604	598
Pacific Northwest West:							
Removals	266	66	455	452	449	449	449
Inventory	33,621	51,399	57,594	62,019	66,106	69,856	73,413
Net annual growth	320	778	907	873	830	811	792
Pacific Northwest East:							
Removals	330	72	295	294	293	293	293
Inventory	17,338	23,915	24,831	25,450	25,962	26,445	26,939
Net annual growth	269	320	361	346	341	341	344
Alaska:							
Removals	99	51	29	29	29	29	29
Inventory	18,733	18,733	19,290	19,847	20,404	20,961	21,518
Net annual growth	85	85	85	85	85	85	85
United States:							
Removals	1,679	629	1,866	1,900	1,934	1,936	1,935
Inventory	185,575	222,326	249,132	268,517	285,470	300,260	313,634
Net annual growth	2,747	3,430	3,890	3,676	3,458	3,308	3,191

Table 23—Hardwood removals, inventory, and growth on national forests, 1991 and 1997 with projections to 2050 under the 1989 RPA scenario

			Projections				
Region	**1991**	**1997**	**2010**	**2020**	**2030**	**2040**	**2050**
				Million cubic feet			
Northeast:							
Removals	22	17	15	16	13	13	13
Inventory	3,711	3,696	4,152	4,600	5,021	5,435	5,812
Net annual growth	88	69	61	58	56	52	49
North Central:							
Removals	61	64	55	58	60	60	60
Inventory	5,228	6,282	7,733	8,590	9,133	9,590	10,015
Net annual growth	123	139	153	115	107	103	102
Southeast:							
Removals	13	51	30	32	34	33	33
Inventory	5,565	5,773	7,144	7,793	8,187	8,425	8,589
Net annual growth	114	105	112	83	63	52	48
South Central:							
Removals	36	56	96	104	112	111	112
Inventory	4,959	5,249	6,258	6,768	7,127	7,360	7,489
Net annual growth	147	144	152	146	140	129	121
West:							
Removals	54	11	48	49	51	50	51
Inventory	6,178	8,613	10,144	11,433	12,428	13,368	14,351
Net annual growth	71	214	188	152	143	150	146
Alaska:							
Removals	N/A	0.4	0.3	0.3	0.3	0.3	0.3
Inventory	N/A	176	214	252	290	328	366
Net annual growth	N/A	4.1	4	4	4	4	4
United States:							
Removals	186	199	244	258	270	268	269
Inventory	25,641	29,789	35,645	39,436	42,186	44,506	46,622
Net annual growth	543	674	670	557	512	489	469

N/A = not available.

Table 24—Softwood removals, inventory, and growth on national forests, 1991 and 1997 with projections to 2050 under the 1993 RPA scenario

Region	1991	1997	Projections				
			2010	2020	2030	2040	2050
			Million cubic feet				
Northeast:							
Removals	5	5	6	5	6	5	6
Inventory	723	782	1,033	1,100	1,161	1,215	1,267
Net annual growth	17	14	13	12	11	11	10
North Central:							
Removals	48	25	36	39	42	42	42
Inventory	3,216	3,646	4,377	4,730	5,004	5,187	5,370
Net annual growth	84	95	74	70	60	60	61
Southeast:							
Removals	59	47	48	50	51	47	52
Inventory	2,826	2,991	3,812	4,193	4,373	4,487	4,574
Net annual growth	50	57	102	76	65	61	60
South Central:							
Removals	169	139	128	131	134	124	136
Inventory	6,013	6,396	6,844	7,099	7,237	7,404	7,547
Net annual growth	174	192	165	149	148	148	147
Rocky Mountains:							
Removals	389	130	315	333	353	353	353
Inventory	71,657	84,925	100,619	112,851	123,489	132,308	139,662
Net annual growth	1,285	1,273	1,582	1,455	1,281	1,126	999
Pacific Southwest:							
Removals	314	96	93	91	91	91	91
Inventory	31,448	29,539	36,683	42,188	47,762	53,330	58,811
Net annual growth	463	616	641	647	650	642	633
Pacific Northwest West:							
Removals	266	66	99	99	98	101	98
Inventory	33,621	51,399	61,985	69,914	77,364	84,264	90,726
Net annual growth	320	778	905	861	801	760	714
Pacific Northwest East:							
Removals	330	72	142	141	140	140	140
Inventory	17,338	23,915	26,898	29,127	31,166	33,037	34,764
Net annual growth	269	320	371	350	332	317	304
Alaska:							
Removals	99	51	29	29	29	29	29
Inventory	18,733	18,733	19,290	19,847	20,404	20,961	21,518
Net annual growth	85	85	85	85	85	85	85
United States:							
Removals	1,679	629	895	917	944	932	947
Inventory	185,575	222,326	261,541	291,049	317,960	342,193	364,239
Net annual growth	2,747	3,430	3,936	3,704	3,433	3,209	3,012

Table 25—Hardwood removals, inventory, and growth on national forests, 1991 and 1997 with projections to 2050 under the 1993 RPA scenario

Region	1991	1997	Projections 2010	2020	2030	2040	2050
			Million cubic feet				
Northeast:							
Removals	22	17	23	25	25	26	25
Inventory	3,711	3,696	4,061	4,439	4,780	5,099	5,391
Net annual growth	88	69	62	59	58	56	52
North Central:							
Removals	61	64	80	84	88	88	87
Inventory	5,228	6,282	7,395	7,962	8,213	8,396	8,577
Net annual growth	123	139	149	112	106	105	108
Southeast:							
Removals	13	51	14	15	15	20	14
Inventory	5,565	5,773	7,302	8,080	8,590	8,912	9,138
Net annual growth	114	105	126	92	67	52	45
South Central:							
Removals	36	56	39	41	42	55	43
Inventory	4,959	5,249	6,871	7,908	8,772	9,397	9,777
Net annual growth	147	144	149	138	120	97	74
West:							
Removals	54	11	41	42	43	40	43
Inventory	6,178	8,613	10,226	11,614	12,715	13,755	14,862
Net annual growth	71	214	190	156	144	152	151
Alaska:							
Removals	N/A	0.4	0.3	0.3	0.3	0.3	0.3
Inventory	N/A	176	214	252	290	328	366
Net annual growth	N/A	4	4	4	4	4	4
United States:							
Removals	186	199	197	207	213	228	213
Inventory	25,641	29,789	36,069	40,255	43,360	45,887	48,111
Net annual growth	543	674	680	562	499	466	433

N/A = not available.

Table 26—Softwood removals, inventory, and growth on national forests, 1991 and 1997 with projections to 2050 under the zero cut scenario without disturbance

			Projections				
Region	**1991**	**1997**	**2010**	**2020**	**2030**	**2040**	**2050**
			Million cubic feet				
Northeast:							
Removals	5	5	—	—	—	—	—
Inventory	723	782	1,098	1,215	1,318	1,411	1,495
Net annual growth	17	14	12	11	10	9	8
North Central:							
Removals	48	25	—	—	—	—	—
Inventory	3,216	3,646	4,898	5,671	6,347	6,914	7,427
Net annual growth	84	95	80	72	59	52	49
Southeast:							
Removals	59	47	—	—	—	—	—
Inventory	2,826	2,991	4,405	5,183	5,667	5,987	6,224
Net annual growth	50	57	97	62	39	27	21
South Central:							
Removals	169	139	—	—	—	—	—
Inventory	6,013	6,396	8,251	9,468	10,402	11,142	11,655
Net annual growth	174	192	141	106	85	65	40
Rocky Mountains:							
Removals	389	130	—	—	—	—	—
Inventory	71,657	84,925	104,735	120,410	134,478	146,541	157,005
Net annual growth	1,285	1,273	1,608	1,474	1,251	1,103	916
Pacific Southwest:							
Removals	314	96	—	—	—	—	—
Inventory	31,448	29,539	37,920	44,472	51,134	57,818	64,408
Net annual growth	463	616	651	664	671	663	651
Pacific Northwest West:							
Removals	266	66	—	—	—	—	—
Inventory	33,621	51,399	63,307	72,122	80,361	87,973	95,097
Net annual growth	320	778	897	845	775	729	675
Pacific Northwest East:							
Removals	330	72	—	—	—	—	—
Inventory	17,338	23,915	28,819	32,547	35,996	39,150	42,018
Net annual growth	269	320	381	354	324	295	268
Alaska:							
Removals	99	51	29	29	29	29	29
Inventory	18,733	18,733	19,290	19,847	20,404	20,961	21,518
Net annual growth	85	85	85	85	85	85	85
United States:							
Removals	1,679	629	29	29	29	29	29
Inventory	185,575	222,326	272,723	310,935	346,107	377,897	406,847
Net annual growth	2,747	3,430	3,952	3,672	3,298	3,026	2,712

Table 27—Hardwood removals, inventory, and growth on national forests, 1991 and 1997 with projections to 2050 under the zero cut scenario without disturbance

Region	1991	1997	Projections 2010	2020	2030	2040	2050
			Million cubic feet				
Northeast:							
Removals	22	17	—	—	—	—	—
Inventory	3,711	3,696	4,331	4,914	5,456	5,961	6,420
Net annual growth	88	69	60	55	52	47	43
North Central:							
Removals	61	64	—	—	—	—	—
Inventory	5,228	6,282	8,520	10,025	11,200	12,243	13,193
Net annual growth	123	139	163	122	107	98	89
Southeast:							
Removals	13	51	—	—	—	—	—
Inventory	5,565	5,773	7,486	8,383	8,981	9,381	9,661
Net annual growth	114	105	110	76	49	33	24
South Central:							
Removals	36	56	—	—	—	—	—
Inventory	4,959	5,249	7,303	8,659	9,805	10,687	11,234
Net annual growth	147	144	144	128	105	72	42
West:							
Removals	54	11	—	—	—	—	—
Inventory	6,178	8,613	10,757	12,538	14,025	15,430	16,825
Net annual growth	71	214	189	152	141	140	138
Alaska:							
Removals	N/A	0.4	0.3	0.3	0.3	0.3	0.3
Inventory	N/A	176	214	252	290	328	366
Net annual growth	N/A	4.1	4	4	4	4	4
United States:							
Removals	186	199	0.3	0.3	0.3	0.3	0.3
Inventory	25,641	29,789	38,611	44,771	49,757	54,030	57,699
Net annual growth	543	674	669	537	457	395	341

N/A = not available.

Table 28—Softwood removals, inventory, growth on national forests, 1991 and 1997 with projections to 2050 under the zero cut with disturbance scenario

Region	1991	1997	Projections 2010	2020	2030	2040	2050
			Million cubic feet				
Northeast:							
Removals	5	5	—	—	—	—	—
Inventory	723	782	1,097	1,214	1,316	1,409	1,492
Net annual growth	17	14	12	11	10	9	8
North Central:							
Removals	48	25	—	—	—	—	—
Inventory	3,216	3,646	4,896	5,663	6,336	6,900	7,411
Net annual growth	84	95	79	71	58	52	48
Southeast:							
Removals	59	47	—	—	—	—	—
Inventory	2,826	2,991	4,356	5,094	5,544	5,837	6,055
Net annual growth	50	57	93	58	36	25	20
South Central:							
Removals	169	139	—	—	—	—	—
Inventory	6,013	6,396	8,152	9,303	10,175	10,863	11,337
Net annual growth	174	192	134	100	79	60	37
Rocky Mountains:							
Removals	389	130	—	—	—	—	—
Inventory	71,657	84,925	101,843	114,684	125,927	135,302	143,081
Net annual growth	1,285	1,273	1,328	1,183	988	819	681
Pacific Southwest:							
Removals	314	96	—	—	—	—	—
Inventory	1,448	29,539	36,360	41,463	46,415	51,174	55,676
Net annual growth	463	616	515	500	484	458	432
Pacific Northwest West:							
Removals	266	66	—	—	—	—	—
Inventory	33,621	51,399	62,417	70,448	77,897	84,726	91,082
Net annual growth	320	778	819	766	697	650	602
Pacific Northwest East:							
Removals	330	72	—	—	—	—	—
Inventory	17,338	23,915	28,371	31,669	34,668	37,364	39,783
Net annual growth	269	320	339	309	278	250	224
Alaska:							
Removals	99	51	29	29	29	29	29
Inventory	18,733	18,733	19,290	19,847	20,404	20,961	21,518
Net annual growth	85	85	85	85	85	85	85
United States:							
Removals	1,679	629	29	29	29	29	29
Inventory	185,575	222,326	266,782	299,385	328,682	354,536	377,435
Net annual growth	2,747	3,430	3,403	3,083	2,715	2,407	2,138

Table 29—Hardwood removals, inventory, growth on national forests, 1991 and 1997 with projections to 2050 under the zero cut with disturbance scenario

			Projections				
Region	1991	1997	2010	2020	2030	2040	2050
				Million cubic feet			
Northeast:							
Removals	22	17	—	—	—	—	—
Inventory	3,711	3,696	4,325	4,902	5,439	5,939	6,394
Net annual growth	88	69	59	55	52	47	43
North Central:							
Removals	61	64	—	—	—	—	—
Inventory	5,228	6,282	8,508	9,993	11,152	12,180	13,116
Net annual growth	123	139	161	120	106	96	88
Southeast:							
Removals	13	51	—	—	—	—	—
Inventory	5,565	5,773	7,384	8,197	8,719	9,060	9,296
Net annual growth	114	105	101	67	42	28	21
South Central:							
Removals	36	56	—	—	—	—	—
Inventory	4,959	5,249	7,204	8,468	9,520	10,318	10,805
Net annual growth	147	144	135	119	95	65	37
West:							
Removals	54	11	—	—	—	—	—
Inventory	6,178	8,613	10,690	12,344	13,731	15,031	16,327
Net annual growth	71	214	175	143	130	131	126
Alaska:							
Removals	N/A	0.4	0.3	0.3	0.3	0.3	0.3
Inventory	N/A	176	214	252	290	328	366
Net annual growth	N/A	4.1	4	4	4	4	4
United States:							
Removals	186.0	199	0.3	0.3	0.3	0.3	0.3
Inventory	25,641.0	29,789	38,325	44,156	48,851	52,856	56,304
Net annual growth	543.0	674	635	508	428	371	318

N/A = not available.

Table 30—List of scientific names for common tree species of the United States

Common name	Scientific name
Alpine fir (subalpine fir)	*Abies lasiocarpa* (Hook.) Nutt.
Apache pine	*Pinus engelmannii* Carr.
Arizona pine	*Pinus ponderosa* var. *arizonica* (Engelm.) Shaw
Ash	*Fraxinus* spp.
Aspen	*Populus* spp.
Balsam fir	*Abies balsamea* (L.) Mill.
Balsam poplar	*Populus balsamifera* L.
Basswood	*Tilia* spp.
Beech	*Fagus* spp.
Birch	*Betula* spp.
Blackgum (black tupelo)	*Nyssa sylvatica* Marsh. var. *sylvatica*
Black walnut	*Juglans nigra* L.
Chestnut oak	*Quercus muehlenbergii* Engelm.
Chihuahua pine	*Pinus* (associates with Apache pine)
Colorado blue spruce	*Picea pungens* Engelm.
Cottonwood	*Populus* spp.
Cypress	*Taxodium* spp.
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Eastern white pine	*Pinus strobus* L.
Elm	*Ulmus* spp.
Engelmann spruce	*Picea engelmannii* Parry ex Engelm.
Grand fir	*Abies grandis* (Dougl. ex D. Don) Lindl.
Gray birch (yellow birch)	*Betula alleghaniensis* Britton
Gum	*Liquidambar* spp.
Hackberry	*Celtis occidentalis* L.
Hemlock	*Tsuga* spp.
Hickory	*Carya* spp.
Incense cedar	*Libocedrus decurrens* Torr.
Jack pine	*Pinus banksiana* Lamb.
Jeffrey pine	*Pinus jeffreyi* Grev. & Balf.
Juniper	*Juniperus* spp.
Larch	*Larix* spp.
Limber pine	*Pinus flexilis* James
Loblolly pine	*Pinus taeda* L.
Lodgepole pine	*Pinus contorta* Dougl. ex Loud.
Longleaf pine	*Pinus palustris* Mill.
Maple	*Acer* spp.
Mountain hemlock	*Tsuga mertensiana* (Bong.) Carr.
Oak	*Quercus* spp.
Paper birch	*Betula papyrifera* Marsh.
Pinyon	*Pinus edulis* Engelm.
Ponderosa pine	*Pinus ponderosa* Dougl. ex Laws
Red alder	*Alnus rubra* Bong.
Red pine	*Pinus resinosa* Ait.
Redwood	*Sequoia sempervirens* (D. Don) Endl.
Scrub oak	*Quercus laevis* Walt.

Table 30—List of scientific names for common tree species of the United States (continued)

Common name	Scientific name
Shortleaf pine	*Pinus echinata* Mill.
Silver fir (Pacific silver fir)	*Abies amabilis* Dougl. ex Forbes
Sitka spruce	*Picea sitchensis* (Bong.) Carr.
Slash pine	*Pinus elliottii* Engelm.
Sugar pine	*Pinus lambertiana* Dougl.
Sweetgum	*Liquidambar styraciflua* L.
Sycamore	*Platanus occidentalis* L.
Tamarack	*Larix laricina* (Du Roi) K. Koch
Tanoak	*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.
True firs	*Abies* spp.
Tupelo	*Nyssa* spp.
Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
Western redcedar	*Thuja plicata* Donn ex D. Don
Western white pine	*Pinus monticola* Dougl. ex D. Don
White cedar	*Chamaecyparis thyoides* (L.) B.S.P.
White fir	*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.
White pine	See western white pine
Willow	*Salix* spp.
Yellow-poplar	*Liriodendron tulipifera* L.

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