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Forest Resources of the Lincoln National Forest

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About the author

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Contents

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The Interior West Forest Inventory and Analysis (IWFIA) program of the USDA Forest Service, Rocky Mountain Research Station, as part of its national Forest Inventory and Analysis (FIA) duties, conducted forest resource inventories of the Southwestern Region (Region 3) National Forests. This report presents highlights of the Lincoln National Forest 1997 inventory including population estimates and summaries of commonly requested variables. Any trends or disturbances (such as fire) that have occurred after 1997 will be discussed in future reports on the Lincoln National Forest.

The information presented in this report is based solely on the IWFIA inventory sample (USDA 1995). The data could be summarized in other ways for different purposes (see "For further information" on the inside back cover for the national FIA database and related contacts). Supplemental documentation and inventory terminology can be found in USDA (2002a), O'Brien (2003), or on the World Wide Web at http://www.fs.fed.us/rm/ogden. Changes in terminology or procedures may limit comparisons with previous estimates and summaries for this area. Additional data collected for the Lincoln National Forest, used separately or in combination with IWFIA data, may produce varying results.

Description of the Forest

The Lincoln National Forest administers 1,103,629 acres (USDA 1996), of which 87 percent is classified as forest land and 13 percent nonforest. This report describes the characteristics of the forest land sampled on the Lincoln. Forest land is land that is at least 10 percent stocked (or formerly stocked) with live tally tree species and is greater than 1 acre in size and 120 feet wide. Based on the tree species present, forest land can be further subdivided into two land categories: timberland and woodland (fig. 1). Timberland is forest land with mostly timber species typically used in the wood products industry, such as ponderosa pine and Douglas-fir. Woodland is forest land with mostly woodland species that often have a multistem growth form and are not typically used for industrial wood products, such as pinyon pine, junipers, and oaks. On the Lincoln, 24 percent of the total forest land is timberland while 76 percent is woodland.

Eight percent of the total forest land area administered by the Lincoln is reserved land, such as wilderness areas, meaning that it has been withdrawn from management for production of wood products. The first section of this report presents summaries of timber and woodland species for all forest land, including reserved designations. The subsequent section addresses nonreserved lands only and includes estimates for timber species sampled on the Lincoln.

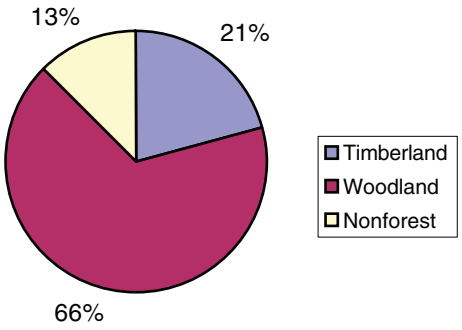

Figure 1—Percent of total area by land category, Lincoln National Forest.

Total Forest Land: highlights of our inventory

Forest type—Forest resources are often described using a forest type classification. Forest type refers to the predominant tree species in a stand, based on plurality of tree stocking. Stocking is an expression of the extent to which growing space is effectively utilized by live trees.

Figure 2 presents the distribution of forest land area on the Lincoln by forest type. Pinyon-juniper is the most common forest type, comprising over 59 percent of the total forest land area. The pure juniper type accounts for another 10 percent of the total forest land area. Douglas-fir is the most common timber forest type, covering just over 10 percent of the forest area. The next most common timber forest types are white fir (8 percent) and ponderosa pine (3 percent). The remaining 10 percent comprises a variety of timber and woodland types including aspen, Engelmann spruce, and miscellaneous western softwoods (timber forest types), plus deciduous woodland oak, mesquite, evergreen oak, and miscellaneous western hardwoods (woodland forest types).

A field plot may sample more than one condition (stand). A forest condition is generally defined as an area of relatively homogeneous vegetative cover that meets the criteria for forest land. Forest type is one of several attributes that define and separate conditions identified on the plot. Table 1 presents the number of conditions and the condition proportions sampled on the Lincoln National Forest by forest type for 172 plots that contained at least one forest condition.

Number of live trees—Forest land can also be examined by looking at the composition of tree species. Figure 3 shows total number of live trees for all sampled tree species

Table 1—Number of conditions and condition proportions on forest land by forest type and land category, Lincoln National Forest, 1997.

Forest type	Number of conditions[a]	Condition proportions[b]
Timberland		
Douglas-fir	21	17.8
White fir	15	13.5
Ponderosa pine	10	5.6
Aspen	3	1.8
Misc. western softwoods	3	1.9
Engelmann spruce	1	0.5
Total Timberland	**53**	**41.1**
Woodland		
Pinyon / juniper	104	96.0
Juniper woodland	18	15.7
Deciduous woodland oak	5	3.6
Evergreen oak	4	4.0
Mesquite	2	2.0
Misc. western hardwoods	2	1.5
Woodland Total	**135**	**122.8**
Grand Total	**188**	**163.9**

[a]Number of conditions by forest type that were sampled. The sum of these numbers is often greater than the total number of plots because a plot may sample more than one forest condition.

[b]Sum of the condition proportions of plots by forest type that were sampled. The sum of these numbers is often less than the total number of plots because of nonforest condition proportions (from plots containing both forest and nonforest conditions) that are not included here.

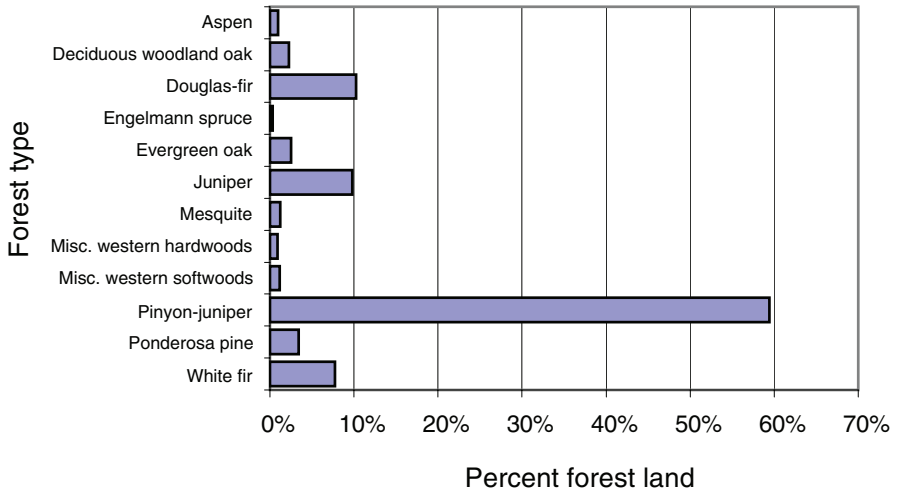

Figure 2—Percent of total forest land by forest type, Lincoln National Forest.

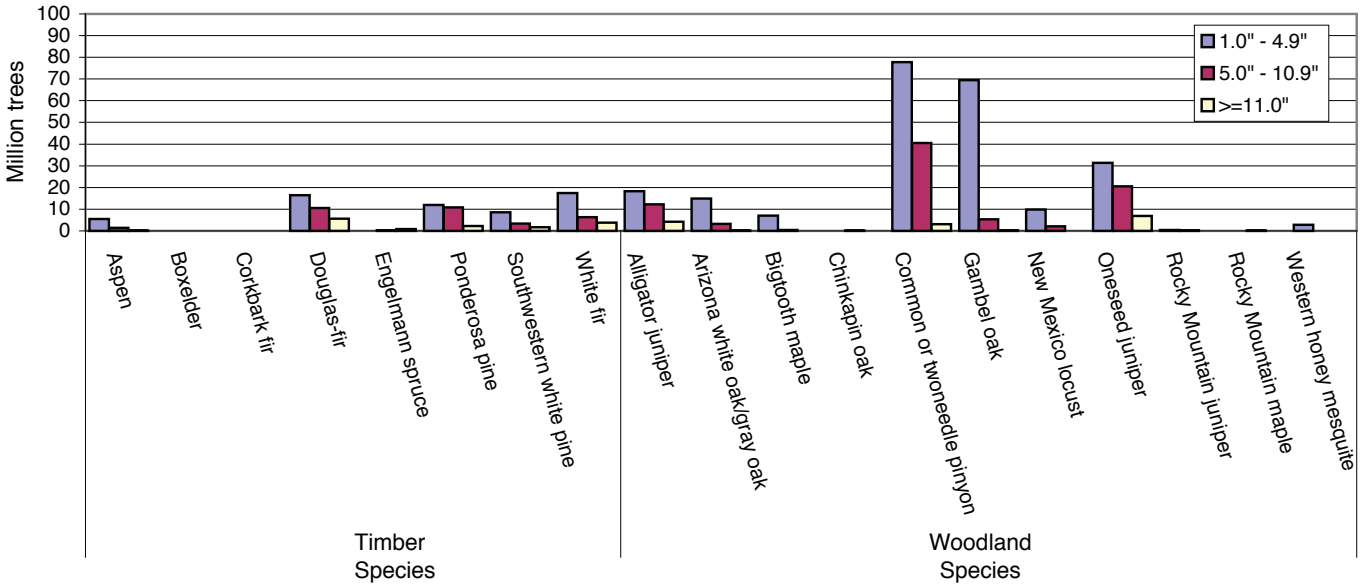

Figure 3—Number of live trees 1 inch diameter and greater on forest land by species and diameter-size class, Lincoln National Forest.

on the Lincoln for three diameter classes. Common or twoneedle pinyon makes up the plurality of live trees at 28 percent. Gambel oak makes up 17 percent and oneseed juniper makes up 13 percent, with most of these less than 5 inches in diameter. The next most common species are alligator juniper (8 percent), Douglas-fir (7 percent), white fir (6 percent), ponderosa pine (6 percent), and Arizona white oak / gray oak (4 percent). The rest of the live trees are found in limited amounts on the Lincoln. Other timber species includes aspen, boxelder, Engelmann spruce, corkbark fir, and southwestern white pine; other woodland species include bigtooth and Rocky Mountain maples, Rocky Mountain juniper, chinkapin oak, New Mexico locust, and western honey mesquite. Species that are scarce may not be encountered with the extensive sampling strategy used for this inventory.

Number and weight of dead trees—Standing and down dead trees are important to forest ecosystems because they provide habitat for many species of wildlife, function as nutrient sinks, and protect the soil from erosion. Approximately 59.4 million standing dead trees (snags) and 9.5 million down dead trees (1 inch diameter and greater) are on Lincoln forest land, with 53.8 snags per acre. Different size snags provide habitat components for many wildlife species. Figure 4 shows the number of snags by

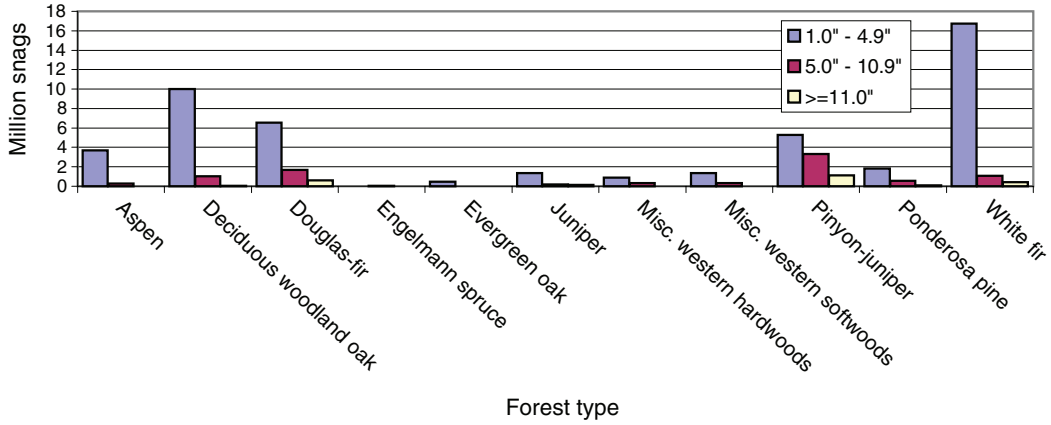

Figure 4—Number of standing dead trees 1 inch diameter and greater on forest land by forest type and diameter-size class, Lincoln National Forest, 1997.

forest type for three diameter classes. Of the total numbers of snags, 81 percent are between 1 inch and 4.9 inches diameter, with nearly 80 percent of these distributed among the white fir, pinyon-juniper, deciduous woodland oak, and Douglas-fir forest types. Of the total numbers of snags, 15 percent are between 5 and 10.9 inches diameter, again with over 80 percent occurring in the same four types as the smaller diameter class. Snags 11 inches diameter or larger make up just over 4 percent of the total, with 2.2 snags per acre. Most of these large snags are found on pinyon-juniper (46 percent), Douglas-fir (26 percent), and white fir (17 percent) forest types.

The amount of dead material can contribute significantly to forest fuel loads and fire potential. Approximately 854 thousand tons of down dead trees and 1.5 million tons of standing dead trees are on Lincoln forest land, with 0.8 tons of down dead trees per acre. This estimate includes the merchantable bole and bark of trees 5 inches diameter and greater. Almost three-quarters of the down dead trees are nearly equally distributed among aspen, common pinyon, and ponderosa pine species. Another 22 percent of down dead trees includes alligator and oneseed junipers, Douglas-fir, and white fir species.

Tree and stand size—The size distribution of trees is an indicator of structural diversity. Figure 5 displays the number of live trees by 2-inch diameter class on the Lincoln, combining trees from all stands. Overall, this shows a typical diameter distribution with a higher number of small trees than large trees.

Stand-size class is a categorization of forest land based on the predominant diameter-size of live trees that contribute to the stocking of a stand. Stocking values for each stand are summed by the following diameter classes. The large diameter class includes softwoods 9 inches diameter and greater, and hardwoods 11 inches diameter and greater; the medium diameter class includes softwoods 5 to 8.9 inches diameter, and hardwoods 5 to 10.9 inches diameter; and the saplings/seedlings class includes all trees under 5 inches diameter. Then each stand (condition) is assigned a class according to stocking predominance. In terms of stocking, fewer large-diameter trees compared to small-diameter trees are required to fully utilize a site; therefore, large-diameter trees have a greater impact on determining stand-size class. Figure 6 displays forest land area on the Lincoln by stand-size class. Approximately 67 percent of the stands have a plurality of stocking from large trees and less than 7 percent are nonstocked, such as stands that have been recently harvested or burned .

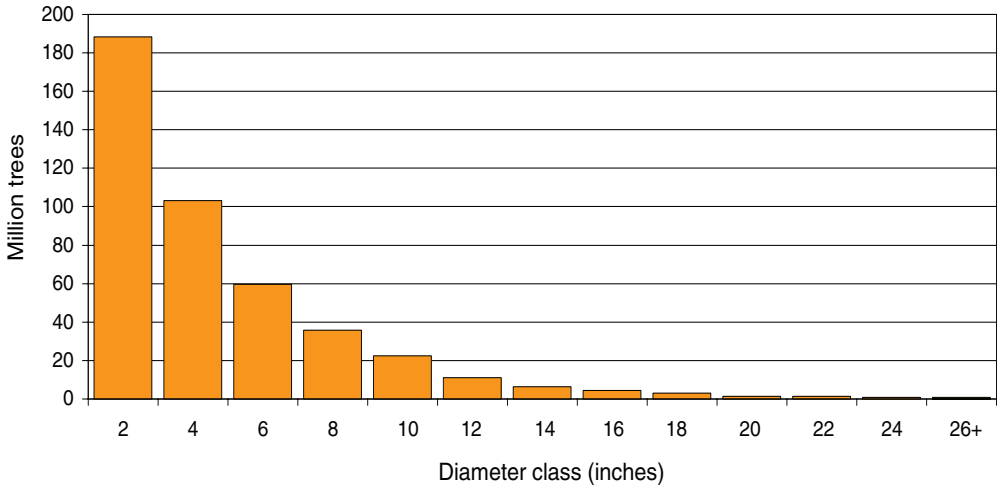

Figure 5—Number of live trees on forest land by 2-inch diameter class, Lincoln National Forest, 1997.

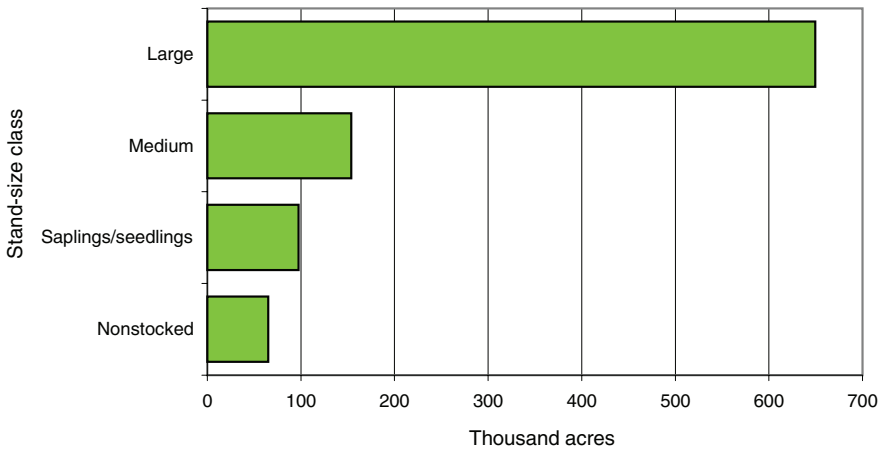

Figure 6—Forest land area by stand-size class, Lincoln National Forest. Large trees include softwoods 9.0"+ and hardwoods 11.0"+; medium trees include softwoods 5.0" to 8.9" and hardwoods 5.0" to 10.9"; saplings/seedlings include trees < 5.0".

Wood volume, biomass, and basal area of live trees—In general, estimates of volume, basal area, and biomass describe the amount of wood fiber in the forest. Each estimate summarizes different portions of a tree and are therefore more appropriate for various forest resource applications. For example, volume relates closely to wood as a product, basal area to forest or tree density, and biomass to forest or tree productivity. In table 2, volume represents the amount of wood fiber in the merchantable bole of a tree, while biomass represents the amount of wood fiber in terms of oven-dry weight including the bole, bark, and branches of the tree. Basal area estimates include the cross-sectional area of a tree stem/bole at the point where diameter is measured. Table 2 shows a breakdown by species of net volume, biomass, and basal area for live trees 5 inches diameter and larger on the Lincoln. Douglas-fir

Table 2—Net volume, biomass, and basal area on forest land by species for trees 5.0 inches diameter and greater, Lincoln National Forest, 1997.

Species	Volume (million cubic feet)	Biomass (million tons)	Basal Area (million square ft.)
Douglas-fir	214.3	4.2	11.3
Common or twoneedle pinyon	168.7	2.0	14.2
White fir	148.7	2.7	7.8
Ponderosa pine	103.9	2.1	6.6
Oneseed juniper	92.6	1.1	15.6
Alligator juniper	85.6	1.0	10.5
Southwestern white pine	66.4	1.1	3.5
Gambel oak	21.9	0.6	1.6
Engelmann spruce	17.1	0.3	1.0
Aspen	12.7	0.3	0.7
New Mexico locust	5.9	0.2	0.6
Arizona white oak / gray oak	3.7	0.1	1.1
Rocky Mountain maple	2.5	†	0.1
Corkbark fir	1.6	†	‡
Rocky mountain juniper	1.0	†	0.1
Bigtooth maple	0.9	†	0.1
Chinkapin oak	0.4	†	‡
Boxelder	§	†	‡
Total (all tree species)	***948.0**	***15.9**	***74.8**

§ less than 100,000 cubic feet
† less than 100,000 tons
‡ less than 100,000 square feet
* numbers may not add to total due to rounding

makes up the plurality of volume (23 percent) and biomass (26 percent), and accounts for 15 percent of the basal area. Common pinyon, the most common tree on the Lincoln, is second in volume (18 percent), third in biomass (13 percent), and second in basal area (19 percent). White fir, ponderosa pine, and oneseed juniper round out the top five species; together, the top five account for approximately three fourths of volume, biomass, and basal area. Although Gambel oak is the second most common tree on the Lincoln (see fig. 3), it accounts for little volume or biomass because most trees of that species are smaller than 5 inches in diameter.

Figure 7 shows the distribution of net volume of wood in trees by 2-inch diameter class on Lincoln forest land. While the number of trees declines with larger diameter classes (see fig. 5), the volume increases significantly from diameter class 6 to 10 inches, where net volume peaks.

Another way to look at wood volume is by forest type, for which per acre estimates can be computed along with biomass and basal area (table 3). These numbers include the many different species that can occur together within each forest type. The highest volume per acre on the Lincoln is in the Engelmann spruce forest type, followed by the white fir and miscellaneous western softwoods types. These three forest types also contain the highest basal area and biomass per acre, because these attributes are strongly correlated with volume.

Many of the forest types listed in table 3 may not be representative due to small sample sizes (see table 1). Only the pinyon-juniper, juniper woodland, Douglas-fir, and white fir forest types have large samples. The mesquite type is not shown in table 3 because volume, biomass, and basal area are not calculated for trees occurring in the type.

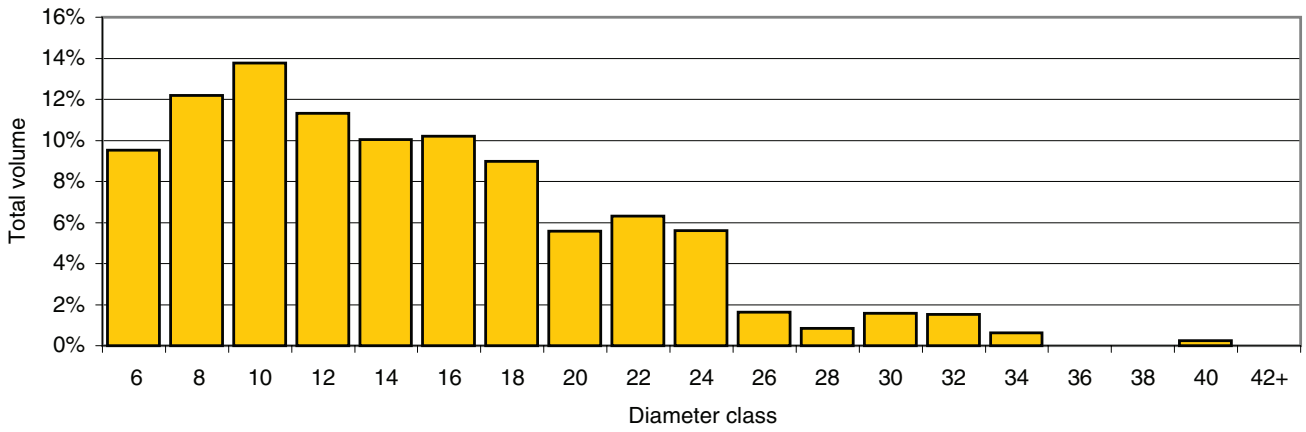

Figure 7—Percent of total net cubic-foot volume of live trees by 2-inch diameter class, Lincoln National Forest.

Table 3—Net cubic foot volume per acre, tons of biomass per acre, and basal area per acre by forest type, Lincoln National Forest, 1997.

Forest Type	Volume (cubic ft. per acre)	Biomass (tons per acre)	Basal area (square feet per acre)
Engelmann spruce	6,111	97.3	334
White fir	3,134	57.7	155
Misc. western softwoods	2,592	48.1	141
Douglas-fir	2,040	39.3	116
Aspen	1,991	44.2	121
Ponderosa pine	1,799	34.8	118
Misc. western hardwoods	678	21.3	72
Pinyon-juniper	614	8.0	69
Deciduous woodland oak	581	14.5	43
Juniper	136	1.8	23
Evergreen oak	88	2.3	21
Average (all types)	**981**	**16.5**	**78**

Stand density index—Many factors influence the rate at which trees grow and thrive, or die. As tree size and density increase, competition for available resources increases. Stand density index (SDI), as developed by Reineke (1933), is a relative measure quantifying the relationship between trees per acre, stand basal area, average stand diameter, and stocking of a forested stand. The concept was developed for even-aged stands, but can also be applied to uneven-aged stands (Long and Daniel 1990, Shaw 2000; see next paragraph for an explanation of even-aged and uneven-aged stands). SDI is usually presented as a percentage of the maximum SDI for each forest type (USDA 1991). SDI was computed for each location using those maximums, and the results were grouped into six classes (fig. 8). A site is considered to be fully occupied at 35 percent of SDI maximum, which marks the onset of competition-related stresses and slowed growth rates (USDA 1991). Based on FIA sample data, nearly 43 percent of all forest stands in the Lincoln National Forest are considered to be fully occupied.

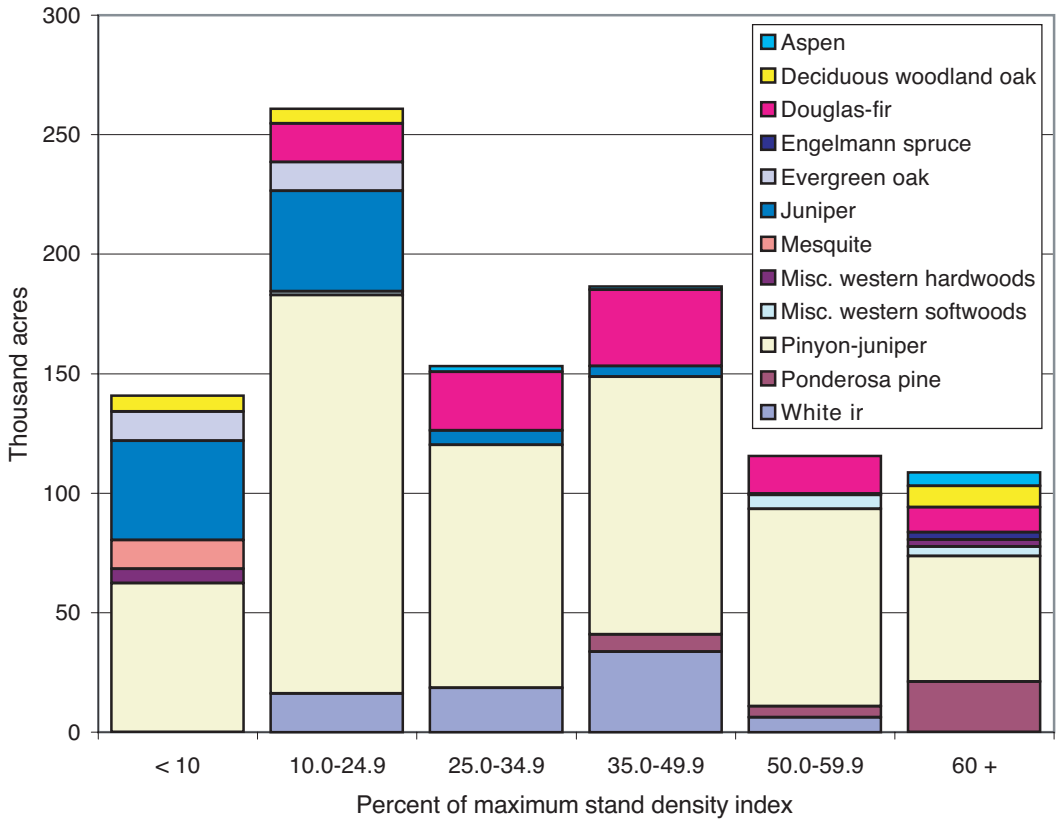

Figure 8—Area of forest land by forest type and percent stand density index, Lincoln National Forest.

Southwest stand structure—Stands may be categorized on the basis of tree size, often in terms of their predominant diameter or height class. This works well for stands where just one or two size classes dominate. Such stands are called single-storied, or even-aged, because they have a structure characterized by a single canopy layer or two closely related layers. Stands having a structure composed of three or more size classes are called multistoried or uneven-aged stands. Both types of structure are important in forest diversity. Differences between single-storied stands provide structural diversity across a landscape. Differences between many layers within a multistoried stand provide vertical diversity.

Figure 9 shows area of forest land by stand structure class and diameter class for four timber softwood forest type groups including pine, mixed conifer, spruce-fir, and "other" timber softwood types. On the Lincoln, the pine category is made up of ponderosa pine, the mixed conifer category includes Douglas-fir and white fir, the spruce-fir category includes Engelmann spruce and corkbark fir, and the "other" category contains miscellaneous softwoods such as Southwestern white pine. The values shown are based on analysis of SDI and tree diameter classes, a method developed by the Southwest Region (USDA 2002b). In general, the Lincoln is represented by both single-storied and multistoried stands. The distribution within single-storied stands occurs mainly in the 5 to 11.9 inch diameter class.

Growth and mortality—Forest vigor can be analyzed by measures of net annual growth and mortality. Net annual growth is the difference between gross annual growth and losses due to mortality. Gross annual growth is the average annual increase in the volume of live trees while mortality is the net volume of trees that have died over a 1 year period based on a 5-year average. Gross annual growth of all live trees 5 inches diameter and greater on all forest land on the Lincoln is estimated to be over 18.7 million cubic feet. Subtracting mortality results in an estimated net annual growth of 14.3 million cubic feet.

Mortality calculations estimate approximately 4.5 million cubic feet of wood from trees 5 inches diameter and greater died on the Lincoln in 1996. Ponderosa pine makes up most of the total mortality volume at over 65 percent with Douglas-fir at 20 percent, common pinyon at 7 percent, and southwestern white pine at 6 percent. Oneseed juniper, Gambel oak, and white fir combined make up the remaining 1 percent of mortality volume on Lincoln forest land. Based on field observations, 58 percent of the mortality on the Lincoln was caused by insects, 32 percent by fire, and 6 percent by disease. The remaining 4 percent was attributed to suppression, weather-related stresses, and unknown causes.

Figure 10 compares gross annual growth to mortality for the seven species that included mortality trees. The largest mortality-to-growth ratio occurs in ponderosa pine where mortality volume is nearly 114 percent of gross growth, yielding negative net growth. All other species show positive net growth.

Understory vegetation—Understory vegetation provides forage and cover for wildlife, contributes to forest fuel load, and can be an indication of the successional stage of the forest community. On each plot field crews visually estimated crown canopy coverage for four plant groups-tree seedlings/saplings, shrubs, forbs, and graminoids (see USDA 1995 for details). Figure 11 shows the average percent cover of plant groups on forest land by forest type. Some forest types, for example aspen, Engelmann spruce, and mesquite, are based on relatively small samples (see table 1).

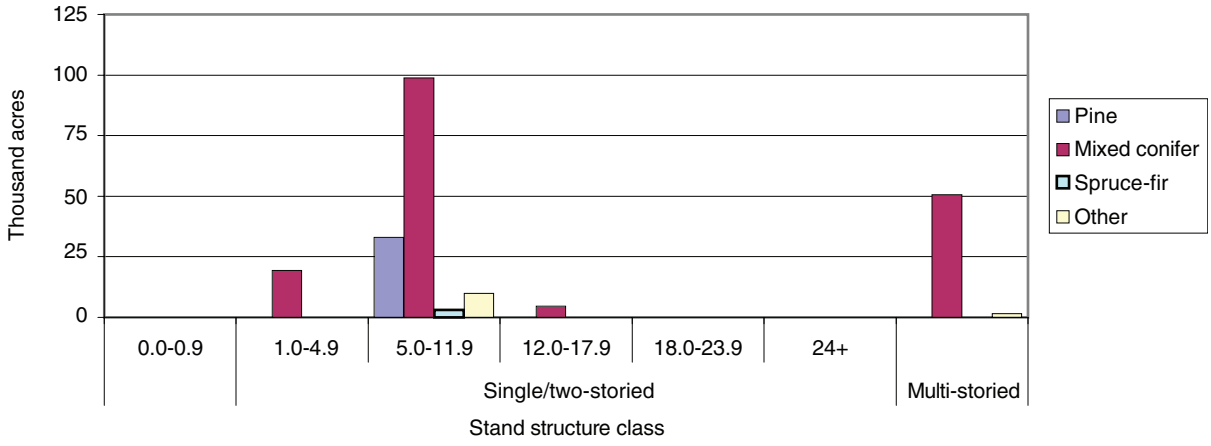

Figure 9—Area of forest land by stand-structure class, diameter class, and timber softwood forest type groups, Lincoln National Forest.

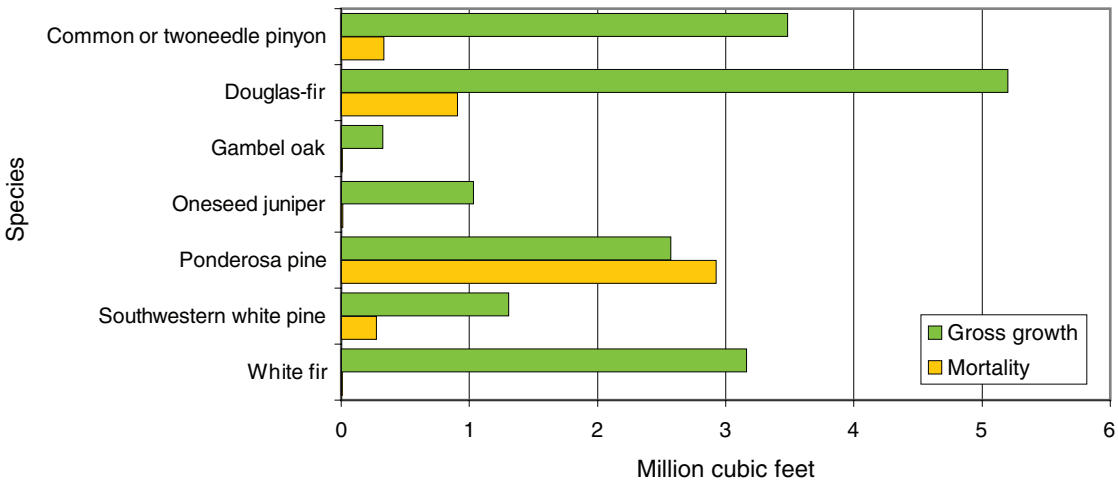

Figure 10—Gross annual growth of live trees 5.0 inches diameter and greater compared to mortality on all forest land, Lincoln National Forest.

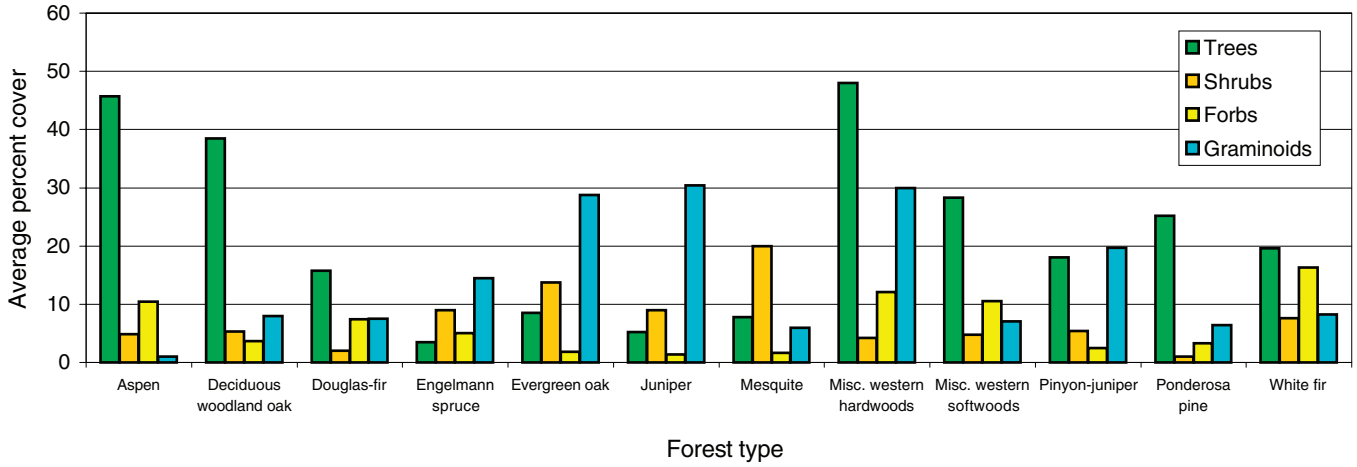

Figure 11—Average percent cover of trees (seedlings/saplings), shrubs, forbs, and graminoids on forest land by forest type, Lincoln National Forest.

Nonreserved timberland: highlights of our inventory

Tree and stand size—Just over 19 percent of forest land in the Lincoln National Forest is nonreserved timberland. The area of nonreserved timberland by stand-size class is presented in figure 12. Similar to all forest land in the Lincoln (see fig. 6), most of the nonreserved timberland area has a plurality of stocking from large trees.

Figure 13 shows the number of growing-stock trees by 2-inch diameter class on nonreserved timberland on the Lincoln. Growing-stock trees are live timber species meeting specific standards of quality and vigor. Of all growing-stock trees on nonreserved timberland on the Lincoln, 25 percent are 9 inches diameter or greater.

Wood volume, biomass, and basal area of growing-stock trees—Table 4 displays a breakdown of net cubic-foot volume, tons of wood biomass, and square foot basal area for growing-stock trees 5 inches diameter and greater by species on nonreserved timberland for the Lincoln. The total net cubic-foot volume of growing stock on nonreserved timberland is about 454 million cubic feet. Douglas-fir

accounts for 40 percent of this volume. The total wood biomass is estimated at 8.4 million tons, with Douglas-fir making up over 41 percent of this amount. Total basal area for growing-stock trees on nonreserved timberland is estimated at over 23 million square feet, with Douglas-fir comprising 39 percent of this total.

The total net sawtimber volume on nonreserved timberland is estimated at 1.7 billion board feet (Scribner rule). Sawtimber includes all growing-stock trees 9 inches and greater for softwoods, and 11 inches diameter and greater for hardwoods. Douglas-fir accounts for 42 percent of this volume, followed by white fir with 25 percent.

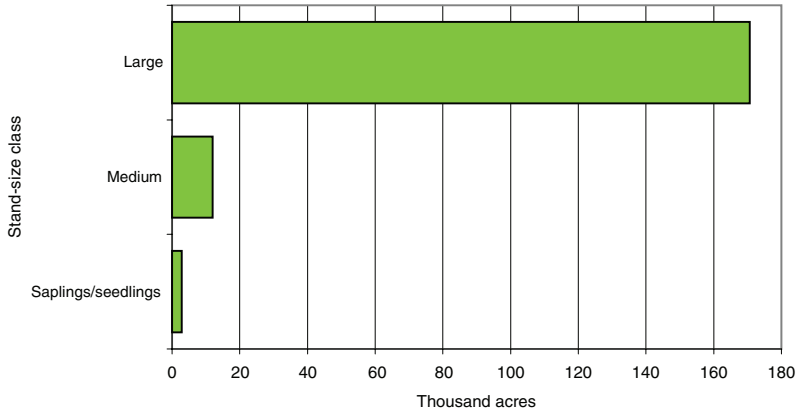

Figure 12—Area of nonreserved timberland by stand-size class, Lincoln National Forest.

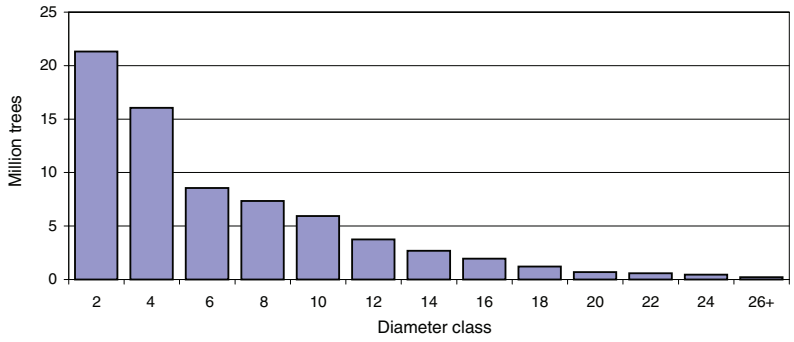

Figure 13—Number of growing-stock trees on nonreserved timberland by 2-inch diameter class, Lincoln National Forest.

Table 4—Net cubic-foot volume, tons of biomass, and square feet of basal area by species on nonreserved timberland, 5.0 inches diameter and greater, Lincoln National Forest, 1997.

Species	Volume (million cubic feet)	Biomass (million tons)	Basal area (million square feet)
Douglas-fir	180.1	3.5	9.0
White fir	114.5	2.0	5.8
Ponderosa pine	65.4	1.3	3.6
Southwestern white pine	63.2	1.1	3.2
Engelmann spruce	17.1	0.3	1.0
Aspen	12.3	0.2	0.6
Corkbark fir	1.6	†	‡
Total*	***454.2**	***8.4**	***23.3**

† less than 100,000 tons
‡ less than 100,000 square feet
* numbers may not add to total due to rounding

Growth and mortality—Gross annual growth of growing-stock trees on nonreserved timberland on the Lincoln is estimated to be 10.0 million cubic feet, while mortality is estimated at 2.1 million cubic feet. This calculates to a net annual growth of 7.9 million cubic feet. Mortality volume was attributed to only three species, with ponderosa pine accounting for almost two-thirds of this total. Gross annual growth is compared to mortality for these three species in figure 14. Mortality for nonreserved timberland on the Lincoln is about 21 percent of gross annual growth. The largest mortality-to-growth ratio occurs in ponderosa pine, where mortality volume is about 96 percent of gross growth, yielding only slightly positive net growth. Gross growth is over 9 times mortality for Douglas-fir and over 4 times mortality for southwestern white pine, yielding much higher net growth for these species. These results compare more favorably to those shown in figure 10 for all live trees 5 inches diameter and greater on all forest land.

The inventory methods

About the two-phase sample design—FIA inventories provide a statistical-based sample of forest resources across all ownerships that can be used for planning and analyses at local, State, regional, and national levels (for further information about the national FIA program, refer to the World Wide Web at http://www.fia.fs.fed.us). IWFIA uses a two-phase sampling procedure for all inventories. Phase one of the inventory is based on a grid of sample points systematically located every 1,000 meters (approximately one sample point per 247 acres) across all lands in the State. Phase one points are assigned ownership and vegetative cover attributes using maps and remotely sensed imagery. Field crews conduct phase two of the inventory on a subsample of the phase one points that occur on forest land. The sampling intensity is one field plot every 5,000 meters (approximately one field plot per 6,178 acres), or about every 3 miles. Phase two plots are stratified based on phase one ownership and vegetation information, and weights are assigned to each stratum based on the proportion of phase one points in that stratum.

Phase two plots were sampled using the mapped-plot design. There were 187 field plots on the Lincoln National Forest, all of which were accessible by inventory crews. A total of 154 field plots sampled only forest conditions, 18 sampled both forest and nonforest conditions, and 15 sampled only nonforest conditions. A total of 188 forest conditions (stands) were sampled on 172 plots that contain 163.8 forest and 8.2 nonforest condition proportions.

About the mapped-plot design—The mapped-plot design was adopted by Forest Inventory and Analysis nationwide by 1995. The predetermined subplot layout uses boundary delineation, when necessary, to classify differing conditions. Most plots sample a single forest condition, therefore delineating conditions is often not required.

Conditions were separated or mapped on differences in any of five attributes: forest/nonforest, forest type, stand-size class, stand origin, and stand density. The condition proportion is the fraction of plot area sampled on each condition. The sum of all condition proportions for a plot equals 1.00. Therefore, the number and relative size of plot conditions determines the weighted area (condition proportion multiplied by expansion factor) used for sample expansion.

Standard errors—The two-phase sampling scheme was designed to meet national standards for precision in State and regional estimates of forest attributes. Standard errors, which denote the precision of an estimate, are usually higher for smaller subsets of data. Percent standard errors for estimates of area, net volume, net annual growth and annual mortality are presented in table 5. Standard errors for other estimates are available upon request (see "For further information" section on the inside back cover).

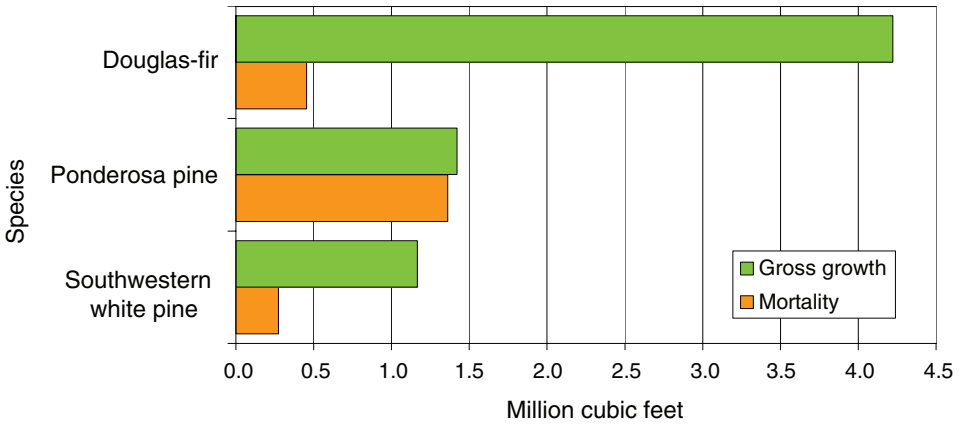

Figure 14—Gross annual growth of growing-stock trees 5 inches diameter and greater compared to mortality on nonreserved timberland,Lincoln National Forest.

Table 5—Percent standard error for area estimate on total forest land, and percent standard errors for estimates of net volume, net annual growth, and annual mortality for all trees on total forest land, and growing-stock trees on nonreserved timberland (5 inches diameter and greater), Lincoln National Forest.

Land class	Attribute	Estimate	Percent standard error
Total forest land (acres)	Area	965,640	±2.6
Total forest land (all trees, million cubic feet)	Volume	948.0	±7.3
	Growth	14.3	±14.9
	Mortality	4.7	±40.1
Nonreserved timberland (growing-stock trees, million cubic feet)	Volume	454.2	±14.5
	Growth	8.0	±21.5
	Mortality	2.1	±62.6

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Selected data for this Forest are part of a national database that houses information for much of the forest land in the United States. This database can be accessed on the Internet at the following web site.

http://ncrs2.fs.fed.us/4801/fiadb/index.htm

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