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Forest Resources of the Coconino National Forest

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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 Coconino National Forest 1995 inventory including population estimates and summaries of commonly requested variables. Any trends or disturbances (such as, fire) that have occurred after 1995 will be discussed in future reports of the Coconino 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 (2002), 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 Coconino National Forest, used separately or in combination with IWFIA data, may produce varying results.

Description of the Forest

The Coconino National Forest administers 1,849,510 acres (USDA 1996) of which 85 percent is classified as forest land and 15 percent nonforest or water. This report describes the characteristics of the forest land sampled on the Coconino. 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 Coconino, 53 percent of the total forest land is timberland while 47 percent is woodland.

Nine percent of the total forest land area administered by the Coconino is reserved land, meaning that it has been

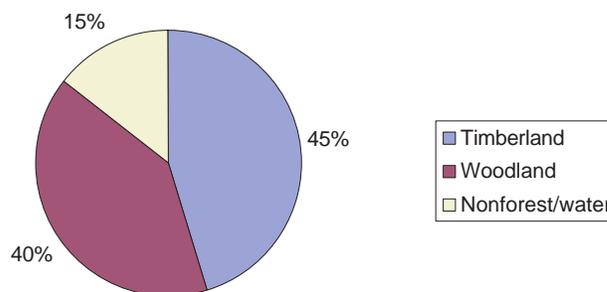
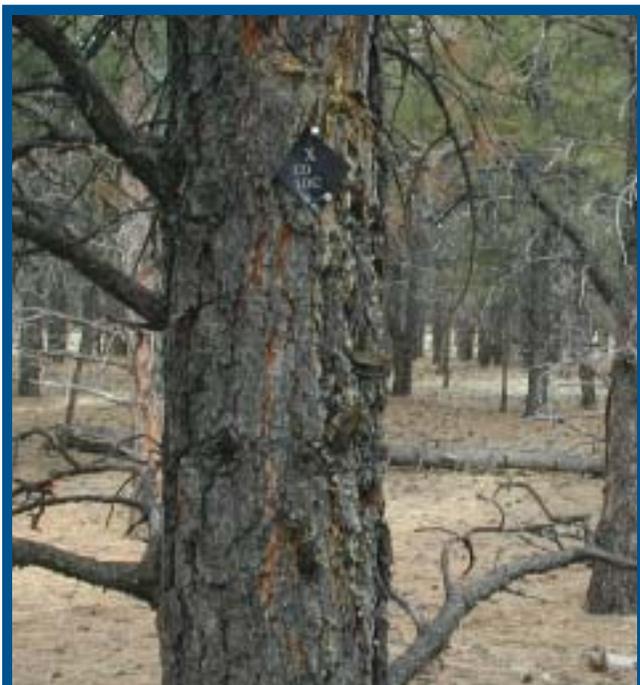


Figure 1—Percent of total area by land category, Coconino National Forest.

withdrawn from management for production of wood products, such as wilderness areas. 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 Coconino.

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 Coconino by forest type. The ponderosa pine forest type is the most common forest type, comprising nearly 48 percent of the total forest land area. Pinyon-juniper and pure juniper types comprise a combined 44 percent of the total forest land area. The remaining 8 percent comprises a variety of timber and woodland types including Douglas-fir, aspen, white fir, miscellaneous western softwoods, and cottonwood (timber forest types), plus deciduous woodland oak, maple woodland, mesquite, 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 Coconino National Forest



by forest type for 255 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 on the Coconino for three diameter classes. Ponderosa pine makes up the plurality of live trees at 45 percent. Gambel oak makes up 14 percent and New Mexico locust 6 percent, with most of these less than 5 inches in diameter. Douglas-fir, common or twoneedle pinyon, and Utah juniper together make up 17 percent of the live trees on the Coconino; white fir and oneseed juniper, 4 percent each; alligator juniper, 3 percent; and aspen and southwestern white pine, 3 percent. Bigtooth maple, Arizona pinyon pine, singleleaf pinyon, and Rocky Mountain juniper together make up 3 percent. The rest of the live trees, which

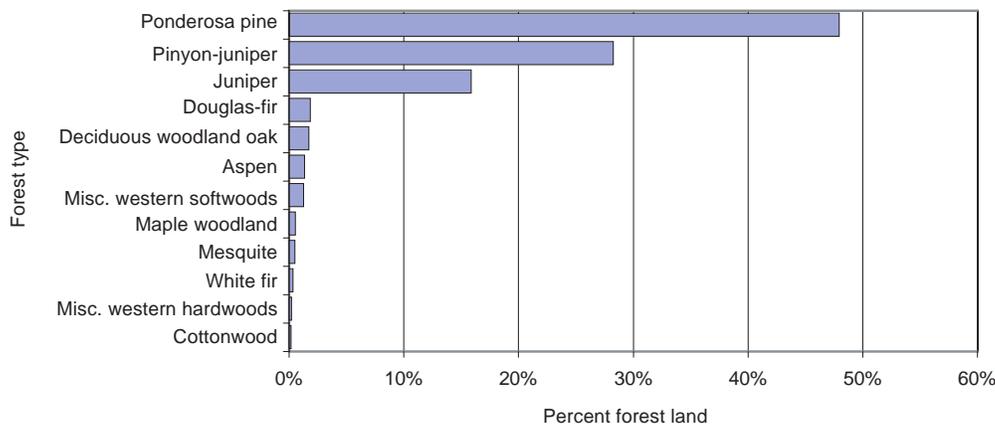


Figure 2—Percent of total forest land area by forest type, Coconino National Forest.

Table 1—Number of conditions and condition proportions on forest land by forest type and land category, Coconino National Forest, 1995.

Forest type	Number of conditions ^a	Condition proportions ^b
Timberland		
Ponderosa pine	147	120.9
Douglas-fir	6	3.7
Aspen	3	2.7
White fir	1	0.9
Cottonwood	1	0.5
Misc. western softwoods	4	3.0
Total timberland	162	131.7
Woodland		
Pinyon-juniper	79	69.4
Juniper	43	41.1
Deciduous woodland oak	4	3.2
Mesquite	2	1.3
Maple woodland	1	0.7
Misc. western hardwoods	1	0.5
Total woodland	130	116.2
Grand total	292	*247.8

^aNumber 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.

^bSum 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.

*Number does not add to total due to rounding

are grouped in the other timber and other woodland species categories, are found in limited amounts on the Coconino. Other timber species includes Arizona cypress, Engelmann spruce, corkbark fir, and narrowleaf cottonwood; other woodland species includes western honey mesquite, Arizona white oak/gray oak, Emory oak, redberry juniper, and velvet 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 28.1 million standing dead trees (snags) and 23.9 million down dead trees (1 inch diameter and greater) are on Coconino forest land, with 17.8 snags per acre. Different size snags provide habitat components for many wildlife species. Figure 4 shows the number of snags by forest type for three diameter classes. Of the total numbers of snags, 59 percent are between 1 inch and 4.9 inches diameter, with nearly two-thirds of these occurring within the ponderosa pine forest type. Of the total numbers of snags, 27 percent are between 5 and 10.9 inches diameter, with approximately half of these occurring within the ponderosa pine forest type. Snags 11 inches diameter or larger make up 14 percent of the total, with 2.5 snags per acre. Most of these large snags are found on ponderosa pine (37 percent) and pinyon-juniper (33 percent) forest types. No snags were sampled in the mesquite, miscellaneous western hardwoods, or cottonwood forest types.

The amount of dead material can contribute significantly to forest fuel loads and fire potential. Approximately 1.8 million tons of down dead trees and 2.2 million tons of

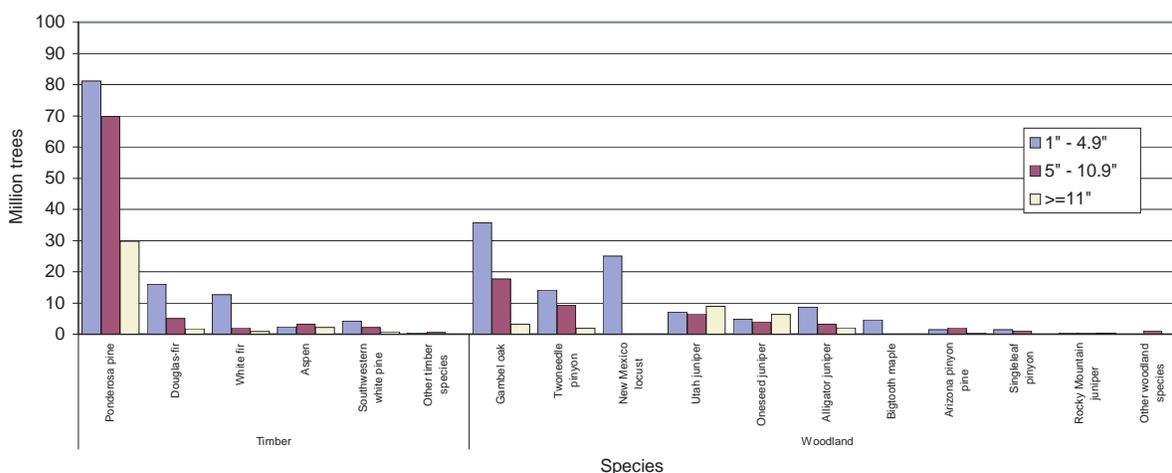


Figure 3—Number of live trees 1 inch diameter and greater on forest land by species and diameter-size class, Coconino National Forest.

standing dead trees are on Coconino forest land, with 1.1 tons of down dead trees per acre. This estimate includes the merchantable bole and bark of trees 5 inches diameter and greater. More than three-quarters of the down dead trees are from ponderosa pine. Another 18 percent comprises pinyon, juniper, and woodland oak 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 Coconino, 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 plurality of stocking of a stand. Stockings 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 the class that has the plurality of stocking. 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 Coconino by stand-size class. Approximately 85 percent of

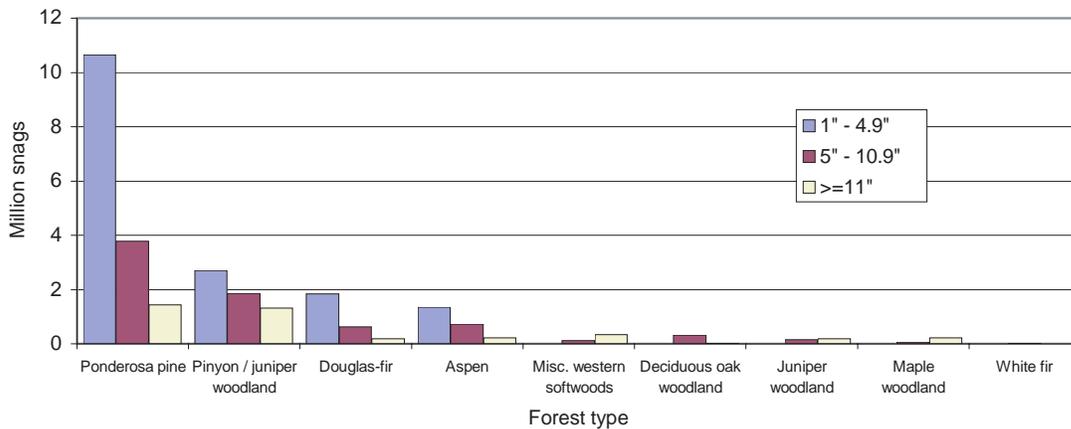


Figure 4—Number of standing dead trees 1 inch diameter and greater on forest land by forest type and diameter-size class, Coconino National Forest.

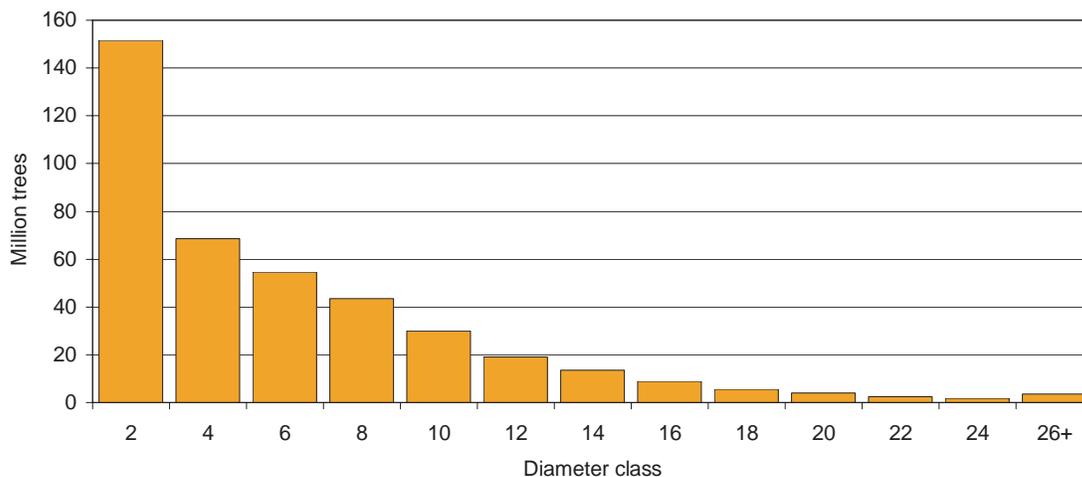


Figure 5—Number of live trees on forest land by 2-inch diameter class, Coconino National Forest.

the stands have a plurality of stocking from large trees and about 9 percent are nonstocked, such as stands that have been recently harvested or burned .

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 Coconino. Ponderosa pine makes up the majority of volume (64 percent) and biomass (67 percent), and accounts for half the basal area. Although relatively abundant in numbers (see fig. 3), New Mexico locust accounts for little volume or biomass because most trees of that species are below 5 inches in diameter.

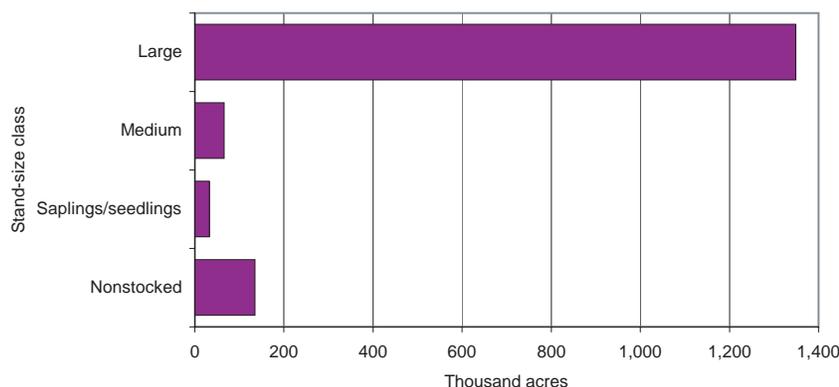


Figure 6—Forest land area by stand-size class, Coconino National Forest. Large trees include softwoods 9 inches and greater, and hardwoods 11 inches and greater; medium trees include softwoods 5 inches to 8.9 inches and hardwoods 5 inches to 10.9 inches; saplings/seedlings include trees less than 5 inches.

Table 2—Net volume, biomass, and basal area on forest land by species, Coconino National Forest, 1995.

Species	Volume (million cubic-feet)	Biomass (million tons)	Basal area (million square feet)
Ponderosa pine	1,189.2	23.5	64.2
Utah juniper	144.4	1.8	19.4
Gambel oak	120.6	3.4	9.5
Oneseed juniper	93.0	1.2	13.4
Aspen	80.6	1.4	3.3
Douglas-fir	74.6	1.5	3.9
Twoneedle pinyon	49.7	0.6	4.8
Alligator juniper	38.3	0.5	4.8
Southwestern white pine	28.1	0.5	1.5
White fir	20.9	0.4	1.4
Arizona pinyon pine	13.8	0.2	1.2
Rocky Mountain juniper	3.3	†	0.4
Singleleaf pinyon	3.1	†	0.3
Engelmann spruce	1.2	†	‡
Other species*	4.4	0.1	0.6
Total** (all tree species)	1,865.4	35.1	128.8

† Less than 100,000 tons

‡ Less than 100,000 sq ft

*Other species include: Arizona white oak/gray oak, Emory oak, Arizona cypress, bigtooth maple, New Mexico locust, redberry juniper, velvet mesquite, western honey mesquite, corkbark fir, and narrowleaf cottonwood

** Numbers do not add to total due to rounding

Figure 7 shows the distribution of net volume of wood in trees by 2-inch diameter class on Coconino forest land. While the number of trees declines with larger diameter classes (see fig. 5), the volume increases significantly from diameter class 6 to 14 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 Coconino is in the aspen forest type, followed by Douglas-fir and miscellaneous western softwoods. 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 type summaries listed in table 3 may not be representative due to small sample sizes (see table 1). Only the ponderosa pine, pinyon-juniper and juniper forest types have large samples.

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; see next paragraph for an explanation of even-aged and uneven-aged stands). SDI is usually presented as a percentage of

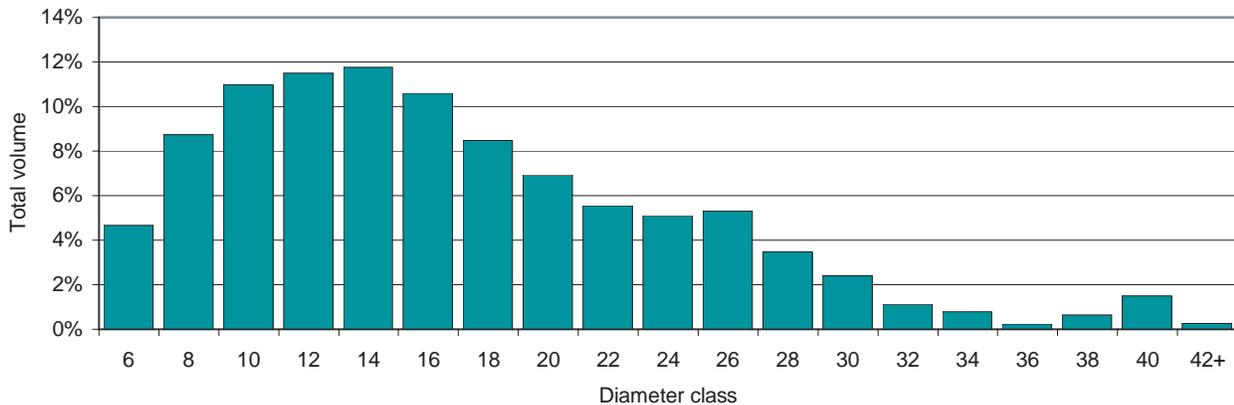
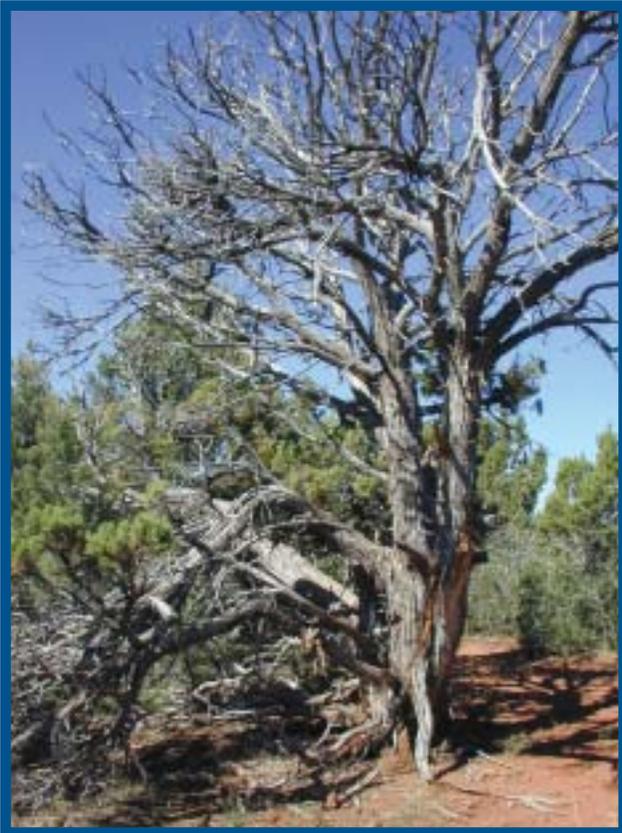


Figure 7—Percent of total net cubic-foot volume of live trees by 2-inch diameter class, Coconino National Forest.

Table 3—Net volume, biomass, and basal area per acre on forest land by forest type, Coconino National Forest, 1995.

Forest type	Volume cubic feet per acre	Biomass tons per acre	Basal area square feet per acre
Aspen	4,564	79.4	192
Douglas-fir	3,124	63.7	158
Misc. western softwoods	2,414	45.0	108
White fir	1,710	35.3	90
Ponderosa pine	1,643	33.3	95
Maple woodland	962	19.6	53
Deciduous woodland oak	786	19.2	51
Pinyon-juniper	605	7.9	73
Juniper	303	4.0	46
Cottonwood	107	1.4	14
Misc. western hardwoods	45	0.5	10
Mesquite*	0	0.0	0
Total (all types)	1,180	22.2	81

* No trees were tallied in the mesquite type



FIA sample data, about 42 percent of all forest stands in the Coconino National Forest are considered to be fully occupied.

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 three timber softwood forest type groups including pine, mixed conifer, and “other” timber softwood types. On the Coconino, the pine category is made up of ponderosa pine, the mixed conifer category includes Douglas-fir and white fir, and the “other” category contains miscellaneous softwoods including Arizona cypress and 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 Coconino is represented by both single-storied and multistoried stands, but the distribution within single-storied stands occurs mainly in the 5-11.9 inch diameter class.

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

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

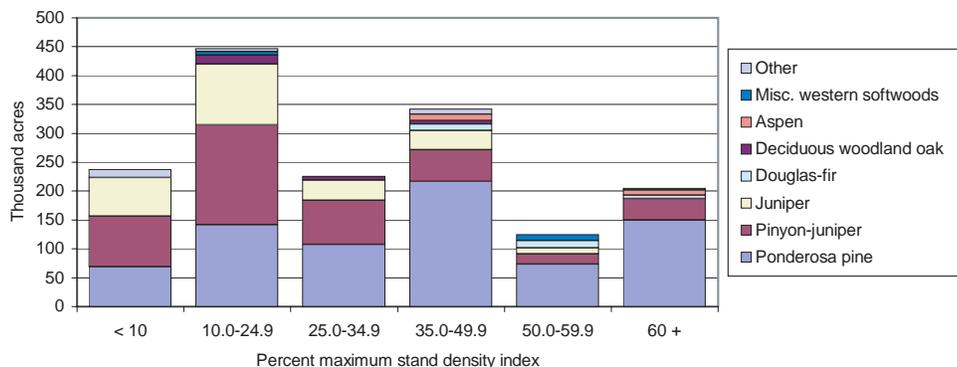


Figure 8—Area of forest land by forest type and percent stand density index, Coconino National Forest. Other category includes maple woodland, mesquite, white fir, misc. western hardwoods, and cottonwood.

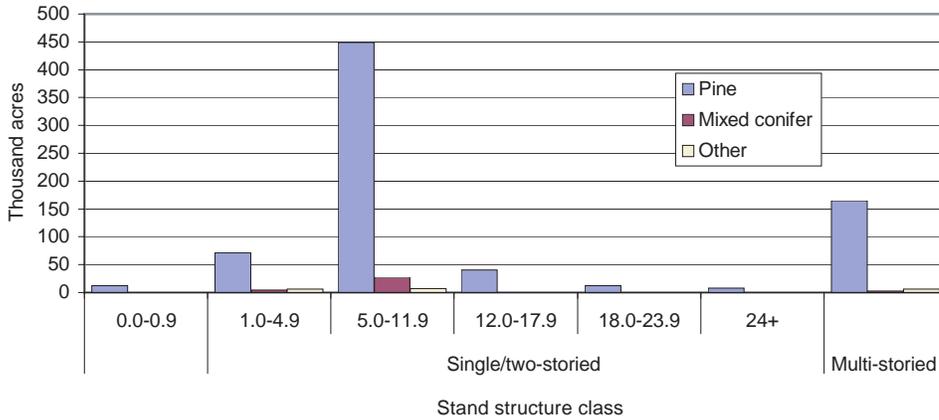


Figure 9—Area of forest land by stand structure class, diameter class, and timber softwood forest type groups, Coconino National Forest.

live trees 5 inches diameter and greater on all forest land on the Coconino is estimated to be 38 million cubic feet. Subtracting mortality results in an estimated net annual growth of 30 million cubic feet.

Mortality calculations estimate approximately 8 million cubic feet of wood 5 inches diameter and greater died on the Coconino in 1994. Douglas-fir makes up most of the total mortality volume at almost 62 percent, with ponderosa pine at 21 percent and aspen at 13 percent. Twoneedle pinyon, Gambel oak, and white fir combine to make up more than 4 percent of the remaining mortality volume on Coconino forest land. Based on field observations, 53 percent of the mortality on the Coconino was caused by disease, 42 percent by insects, and 4 percent by weather-related stresses. The remaining 1 percent was attributed to suppression and unknown causes.

Figure 10 compares gross annual growth to mortality for the six species that included mortality trees. The largest mortality-to-growth ratio occurs in Douglas-fir where mortality volume is nearly twice the 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 maple woodland and white fir, are based on relatively small samples (see table 1).

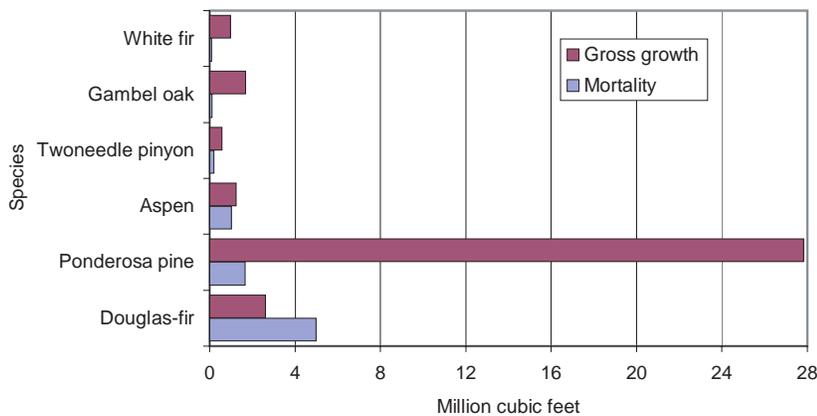


Figure 10—Gross annual growth of live trees 5 inches diameter and greater compared to mortality on all forest land, Coconino National Forest.

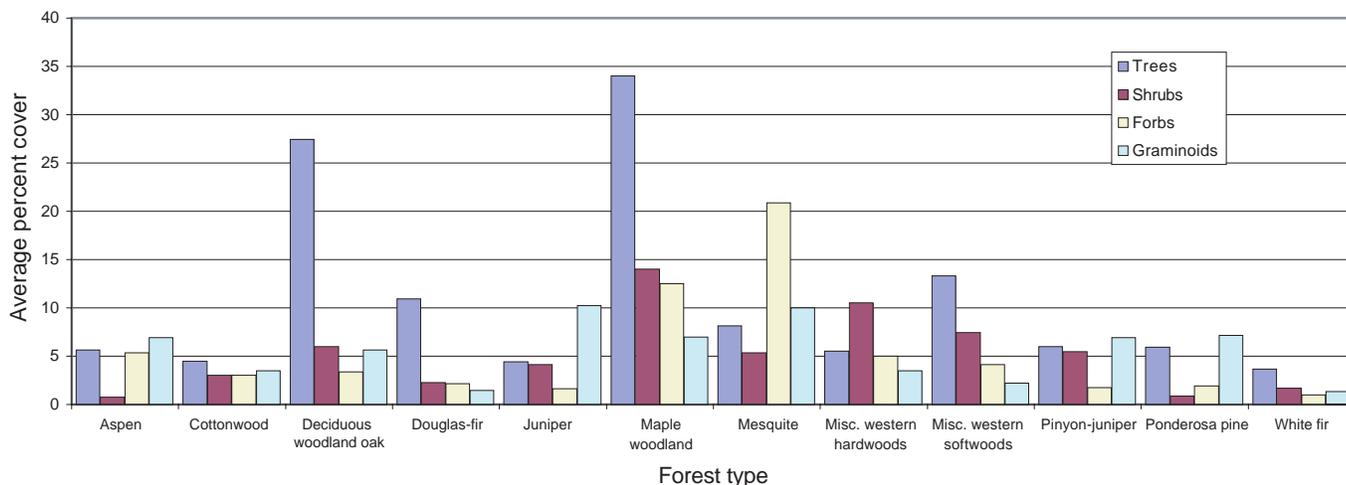
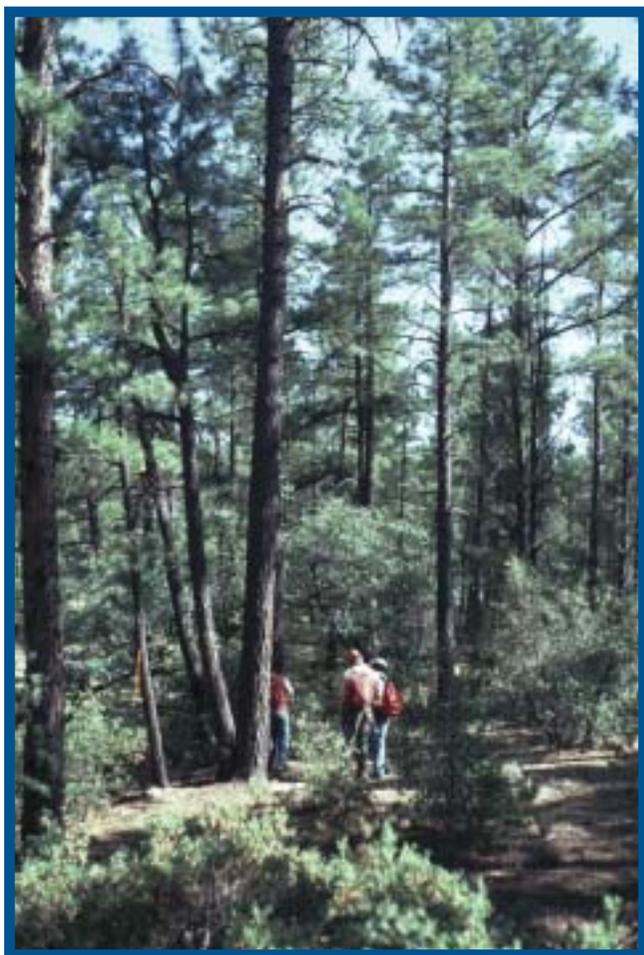


Figure 11—Average percent cover of trees (seedlings/saplings), shrubs, forbs, and graminoids on forest land by forest type, Coconino National Forest.



Nonreserved timberland: highlights of our inventory

Tree and stand size—Almost 50 percent of forest land in the Coconino 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 Coconino (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 Coconino. Growing-stock trees are live timber species meeting specific standards of quality and vigor. Of all growing-stock trees on nonreserved timberland on the Coconino, 27 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 Coconino. The total net cubic-foot volume of growing stock on nonreserved timberland is about 1.2 billion cubic feet. Ponderosa pine accounts for 91 percent of this volume. The total wood biomass is estimated at 23.3 million tons, with ponderosa pine making up over 91 percent of this amount. Total basal area for growing-stock trees on nonreserved timberland is estimated at nearly 65 million square feet, with ponderosa pine comprising 91 percent of this total.

The total net sawtimber volume on nonreserved timberland is estimated at 4.5 billion board feet (Scribner rule). Sawtimber includes all growing-stock trees 9 inches and greater for softwoods, and 11 inches diameter and greater

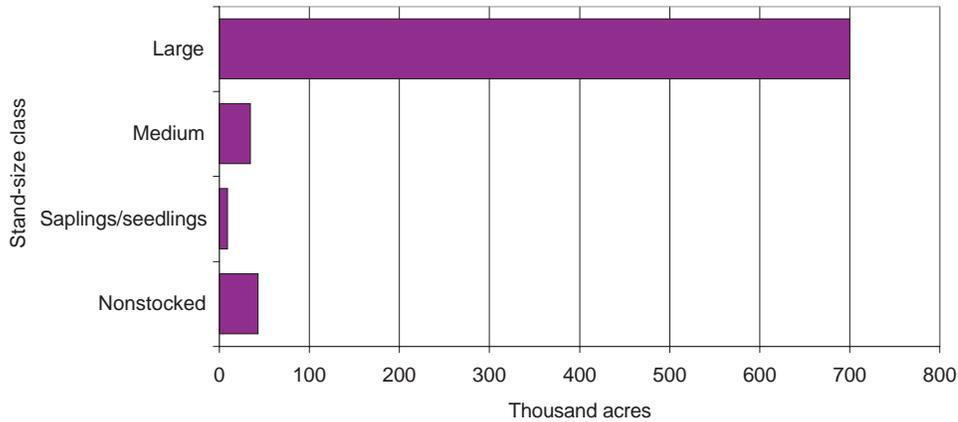


Figure 12—Area of nonreserved timberland by stand-size class, Coconino National Forest.

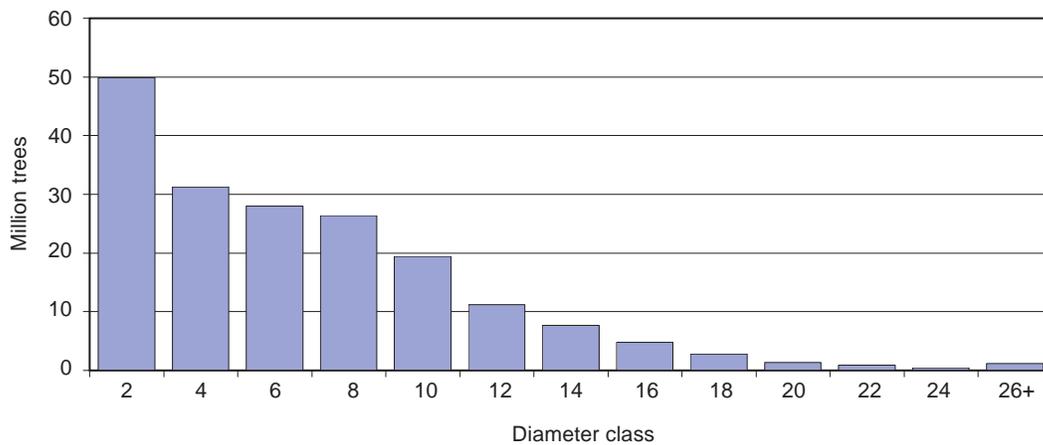


Figure 13—Number of growing-stock trees on nonreserved timberland by 2-inch diameter class, Coconino National Forest.

Table 4—Net volume, biomass, and basal area of growing-stock trees 5 inches diameter and greater by species on nonreserved timberland, Coconino National Forest.

Species	Volume (million cubic feet)	Biomass (million tons)	Basal area (million square feet)
Ponderosa pine	1,081.0	21.3	59.0
Douglas-fir	38.5	0.8	2.1
Aspen	32.5	0.5	1.6
Southwestern white pine	24.7	0.4	1.3
White fir	11.8	0.2	0.8
Arizona cypress	0.7	†	0.1
Corkbark fir	0.7	†	‡
Engelmann spruce	0.4	†	‡
Total*	1,190.4	23.3	64.9

† less than 100,000 tons

‡ less than 100,000 square feet

* numbers may not add to total due to rounding



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>). IWFA 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 301 field plots on the Coconino National Forest, of which nine were determined to be inaccessible. A total of 233 field plots sampled only forest conditions, 22 sampled both forest and nonforest conditions, and 37 sampled only nonforest conditions. A total of 292 forest conditions (stands) were sampled on 255 plots that contain 247.8 forest and 7.2 nonforest/water 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.

for hardwoods. Ponderosa pine accounts for the majority, 93 percent, of this volume.

Growth and mortality—Gross annual growth of growing-stock trees on nonreserved timberland on the Coconino is estimated to be 29.4 million cubic feet, while mortality is estimated at 4.7 million cubic feet. This calculates to a net annual growth of 24.7 million cubic feet. All of the mortality volume was attributed to only four species, with Douglas-fir accounting for nearly two-thirds of this total. Gross annual growth is compared to mortality for these four species in figure 14. Mortality for nonreserved timberland on the Coconino is about 16 percent of gross annual growth, with the largest mortality-to-growth ratio occurring in Douglas-fir, where mortality volume is nearly twice the gross growth, yielding negative net growth. These results are similar to those shown in figure 10 for all live trees 5 inches diameter and greater on all forest land.

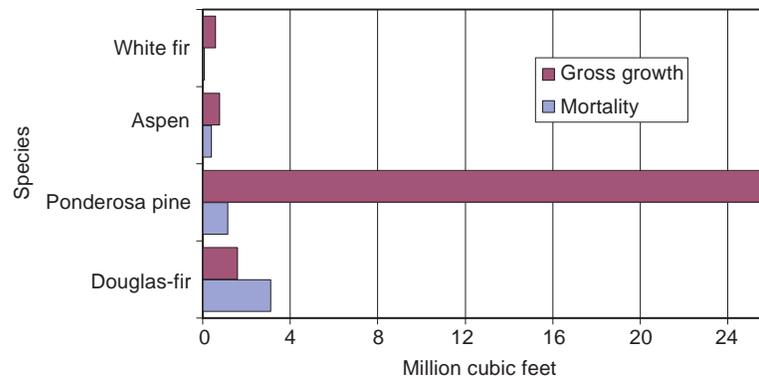


Figure 14—Gross annual growth of growing-stock trees 5 inches diameter and greater compared to mortality on nonreserved timberland, Coconino National Forest.

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).

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 live trees on total forest land, and growing-stock trees on nonreserved timberland (5 inches diameter and greater), Coconino National Forest.

Land class	Attribute	Estimate	Percent standard error
Total forest land (acres)	Area	1,581,321	±2.2
Total forest land (all trees cubic feet)	Volume	1,865,433,886	±6.7
	Growth	30,004,621	±14.2
	Mortality	8,054,847	±46.3
Nonreserved timberland (growing-stock trees cubic feet)	Volume	1,190,365,139	±7.7
	Growth	24,648,472	±14.6
	Mortality	4,733,426	±66.8



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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://www.ncrs.fs.fed.us/4801/fiadb/index.htm>



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Studies accelerate solutions to problems involving ecosystems, range, forests, water, recreation, fire, resource inventory, land reclamation, community sustainability, forest engineering technology, multiple use economics, wildlife and fish habitat, and forest insects and diseases. Studies are conducted cooperatively, and applications may be found worldwide.

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