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California's Forest Resources, 2006–2015: 10-Year Forest Inventory and Analysis Report

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Cover photo: Granite Chief Mountain in Placer County, California, 2016. Photo by R. Snyder.

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Leslie C. Brodie and Marin Palmer

U.S. Department of Agriculture, Forest Service
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Abstract

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Of California's almost 100 million ac, about a third are forested (32 million ac). This report, including the accompanying tables, summarizes key findings from the 5,369 Forest Inventory and Analysis (FIA) plots measured in California's forests during the period 2006–2015. Estimates are provided for forest area, ownership, species composition and distribution, size and age classes, volume, biomass, carbon, dead and downed wood, and understory vegetation. Starting in 2001, plots were measured on a 10-year cycle (10 percent of all plots measured annually). Thus, those plots measured in 2011–2015 represent completion of half of the remeasurement cycle; estimates of growth, mortality, and removals from remeasured plots are also included. The U.S. Forest Service manages about half of California's forested land—48 percent. Fifty-two percent of California's forests is categorized as timberland (unreserved forest land capable of producing ≥20 ft of wood per acre per year) predominantly consisting of the California mixed-conifer type. The most common forest type on the remaining 48 percent was western oak. Mean annual gross growth was 1.99 billion ft/year. Subtracting harvest removals (21 percent of growth values) and mortality (45 percent of growth values) still resulted in a positive net growth of 673 million ft/year. Of some of the commercially important tree species, damage was present in 17 to 27 percent of the trees, including Douglas-fir (17 percent), white fir (27 percent), ponderosa pine (20 percent), and redwood (17 percent). The two most prevalent nonnative species were both grasses—cheatgrass (estimated 277,000 ac of cover*)* and ripgut brome (234,000 ac). During the 10-year period, the years with the most forested acres with evidence of fire were 2008 and 2015. FIA plots will continue to be measured as stipulated by the 1998 Farm Bill. By the time the next FIA report for California is issued, a complete remeasurement cycle will have been completed.

Keywords: Biomass, FIA, Forest Inventory and Analysis, carbon, dead wood, fire, forest land, inventory, ownership, timber volume, timberland, California.

Key Forest Inventory and Analysis Statistics, California 2006–2015

- Number of forested plots measured by FIA program (2006–2015): 5,369
    - Previous measurement period (2001–2010): 5,575
- Estimated total forest area: 31.9 million ac
    - Previous measurement period (2001–2010): 32.8 million ac
- Estimated number of trees: 10.9 billion
    - Previous measurement period (2001–2010): 11.0 billion
- Estimated net live tree volume: 103.3 billion ft
    - Previous measurement period (2001–2010): 99.8 billion ft
- Estimated net volume of sawtimber trees on timberland: 333.8 billion board feet (Scribner)
    - Previous measurement period (2001–2010): 324.9 billion board feet (Scribner)
- Estimated aboveground biomass of live trees ≥1 inch diameter: 2.2 billion U.S. tons (bone dry)
    - No change from previous measurement period (2001–2010).
- Estimated carbon mass of down wood, live and dead trees: 1.4 billion U.S. tons (1.2 billion Mg).
    - No change from previous measurement period (2001–2010).

Contents

Forest Inventory and Analysis—An Overview

In 1928, the Forest Inventory and Analysis (FIA) program was created to continuously monitor the state of the nation's forests. Plot measurements were initially completed at various intervals until passage of the Agricultural Research, Extension, and Education Reform Act of 1998 (known as the Farm Bill), which specified that methodologies were to be consistent at a national level, and that some portion of the inventory was to be completed annually. Most of FIA's Pacific Northwest region (coastal Alaska, Oregon, Washington, and California) now completes 10 percent of inventory plots annually. Consequently, full inventories are completed every 10 years.

Much of this report summarizes data collected on the 5,369 forested plots in California over a 10-year inventory cycle spanning 2006 through 2015. It is an update to the previous report (Christensen 2016), which summarized the data collected between 2001 and 2010. When comparing the two reports, note that they share about half their data in common—plots sampled between 2006 and 2010. Comparisons presented in this report use only those plots that have been remeasured (i.e., plots measured in 2001–2005 and then measured again in 2011–2015), unless otherwise noted. Another factor affecting the validity of comparisons between reports is a change in the definition of forested land that occurred in 2013. Prior to 2013, part of the definition of "forest land" was that it was at least 10 percent stocked with trees within the last 30 years. Beginning in 2013, forest land was instead defined as lands with at least 10 percent tree canopy cover within the last 30 years. Although this change in definition affected only a small number of plots, forest types where cover is relatively sparse—such as those dominated by oaks and other woodland species—may have been disproportionally affected. Detailed information on annual inventory methods and protocols are presented in Christensen et al. (2016), as well as on the Pacific Northwest Research Station (PNW-FIA) website (https://www.fs.fed.us/pnw/rma/).

Other FIA criteria of note are that a "forest" is at least 1 ac in size, is 120 ft wide, and is not developed as a nonforest land use. These criteria exclude many trees in urban settings and within small natural spaces, which are important to human health and well-being. To remedy the omission, FIA, in conjunction with local governments, has begun to collect data in urban areas using a modified protocol. Efforts began in Baltimore, Maryland, in 2014, and results for several cities have been published and are available online. In California, data collection for the first urban forest survey has been completed in San Diego, and the results will be presented separately from rural surveys. Several other California cities have been proposed for urban FIA data collection, including Bakersfield, Fresno, Los Angeles, Modesto, Sacramento, San Francisco, San Jose, and Stockton.

The data presented in this report are but a brief overview of the data available online and in the accompanying summary tables. Previous editions of this report have included printed versions of these tables as appendices, but they are now provided in printable (PDF) electronic form only, with a list of all tables provided in appendix 1. Most of the raw data summarized in this report plus additional information is also available online:

- Accompanying tables: URL https://www.fs.fed.us/pnw/pubs/pnw_gtr983-supplement.pdf
- Methods and protocols: https://www.fs.fed.us/pnw/rma/
- PNW-FIA data available for download: https://www.fs.fed.us/pnw/rma/fia-topics/inventory-data/
- National data available for download: https://www.nrs.fs.fed.us/fia/data-tools/
- Glossary of terms: https://www.nrs.fs.fed.us/fia/data-tools/state-reports/glossary/default.asp
- Previous California report (Christensen et al. 2016): https://www.fs.usda.gov/treesearch/pubs/50397

Some key definitions used in the summary tables and figures in this report can be found below. A full glossary is available in the "Glossary of Terms" Web page listed above.

Forest land—Land that has at least 10 percent crown cover by live tally trees of any size or has had at least 10 percent canopy cover of live tally species in the past, based on the presence of stumps, snags, or other evidence. To qualify, the area must be at least 1 ac in size and 120 ft wide. Forest land includes transition zones, such as areas between forest and nonforest lands that meet the minimal tree stocking/cover and forest areas adjacent to urban and built-up lands.

Roadside, streamside, and shelterbelt strips of trees must have a width of at least 120 ft and continuous length of at least 363 ft to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if they are less than 120 ft wide or less than 1 ac in size. Tree-covered areas in agricultural production settings, such as fruit orchards, or tree-covered areas in urban settings, such as city parks, are not considered forest land. Prior to 2013, FIA used stocking tables values (expressed as the percentage of the total tree density required to fully utilize the growth potential of the land) to define forest based on a minimum of 10 percent stocking rather than canopy cover.

Productive forest land—Forest land that is producing or capable of producing >20 ft of wood per acre per year of wood at culmination of mean annual increment (MAI) without regard to reserved status.

Other forest land—Forested land that is not capable of producing ≥20 ft of wood per acre per year, often occurring on sites with poor soils or low precipitation.

Reserved forest land—Land permanently reserved from wood products utilization through statute or administrative designation. Examples include national forest wilderness areas and national parks and monuments.

Sawtimber tree—A live tree of commercial species containing at least a 12-ft sawlog or two noncontiguous saw logs 8 ft or longer, and meeting regional specifications for freedom from defect. Softwoods must be at least 9.0 inches diameter at breast height (d.b.h.). Hardwoods must be at least 11.0 inches diameter outside bark (d.o.b.).

Tally trees—Trees of species that have been selected to be included in the field inventory/sample, usually because they occur in tree growth form throughout much of their range.

Timberland—Unreserved forest land producing or capable of producing industrial wood at a rate of at least 20 ft of wood per acre per year.

Introduction

The Importance of California's Forests

The forests of California play a significant role in the state's economy and the environment of its rural areas (fig. 1). Economic benefits include both wood and nonwood products, as well as ecosystem services such as soil protection, water quality protection and storage, carbon sequestration, plant and wildlife habitat, and recreation. Residents of the state benefit directly from the goods, services, and employment opportunities that forests produce, as well as the enjoyment and quality of life derived from recreational use. The forests of California also attract tourism—a very significant industry in the state—through activities such as skiing, hiking, hunting, and visits to iconic wilderness areas.

Although California has the second largest amount of urban land cover in the nation (5.3 million ac) (USDA FS 2016a), it also hosts the third largest area of forest land (31.9 million ac) and second largest amount of aboveground biomass (table 1). California's timber industry is an important segment of the state's economy. In 2012, 77 primary forest products facilities reported revenues of about $1.4 billion, and the forest industry employed approximately 52,200 workers, who earn about $3.3 billion annually (McIver et al. 2015).

The national parks and other forested areas of California attract many visitors, add to local economies, and are of historical importance. In 1864, President Abraham Lincoln signed a bill granting Yosemite Valley and the Mariposa Grove of giant sequoias to the state of California. It set aside forests and other natural features for protection so that they could be enjoyed "for public use, resort and recreation" (Mackintosh and McDonnell 2005). The designation was the first of its kind—such is the force of the emotional impact that the forests of the state can inspire. Yosemite National Park alone received more than 4 million visits in 2015 (USDI NPS 2017).

Ecosystem services that forests provide are many, varied, and well documented. Although land managers and policymakers often recognize these services, the economic impact of some of these services can be difficult to quantify. Ecosystem services include soil stabilization,

Figure 1—Forest in Napa County, California, 2016.

Table 1—Ten states with the highest forested land area, 2012

State	Total area	Total forest land	Timberland Area	Timberland Net volume timber	Timberland Total above ground biomass
	Thousand acres	*Thousand acres*	*Thousand acres*	*Million ft^3*	*Million dry tons*
Alaska	365,616	128,577	12,817	37,458	679
Texas	167,188	40,318	14,356	19,824	510
California	99,699	32,057	16,991	71,791	1,396
Montana	93,149	25,169	19,629	40,088	740
Oregon	61,432	29,787	24,117	94,301	1,825
Georgia	36,809	24,768	24,352	41,462	1,044
Alabama	32,413	22,877	22,800	35,039	900
Washington	42,532	22,435	18,081	72,011	1,364
Idaho	52,892	21,247	16,772	45,298	796
Michigan	36,185	20,127	19,463	33,695	846

Note: Data represented here are estimates using varying protocols and methodologies and may not add to totals because of rounding.
Source: Oswalt et al. 2014.

carbon storage, water regulation, aesthetic amenity, recreation, and the provision of wildlife and plant habitat (Binder 2017, USDA 2012). About 50 percent of the state's water supply originates from national forests, which, in this agriculturally rich state, is valued at about $9.5 billion annually (USFS FS 2017b). California is also home to 15 endemic tree species (fig. 2), two of which are threatened or endangered—the Santa Cruz and Butano Ridge cypresses (*Hesperocyparis abramsiana* vars. *abramsiana* and *butanoensis*) (California Native Plant Society 2017).

California's forests face many pressures. The state is expected to have the greatest amount in the nation of rural land (both forest and nonforest) being converted to urban use from 2010 to 2060 —9.1 million ac (USDA FS 2016a). Increases in the amount of the wildland-urban interface may increase the incidence of human-caused fires (Syphard et al. 2007). Severe drought and pathogens, most notably bark beetles, are causing unprecedented levels of tree mortality in concentrated areas, prompting Governor Jerry Brown to declare a state of emergency and to convene a tree mortality task force (USDA FS 2016b).

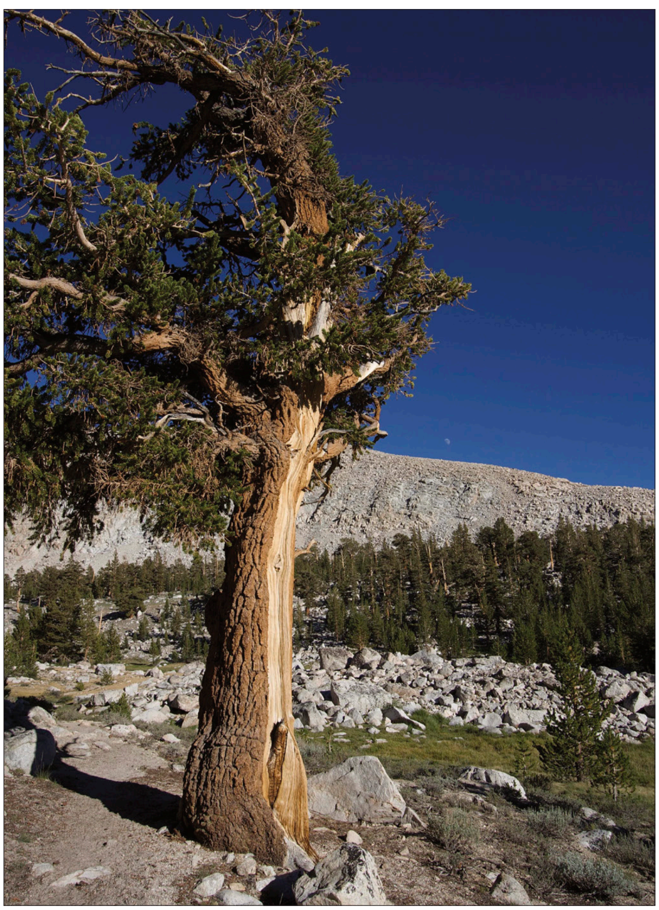


Figure 2—Foxtail pine (*Pinus balfouriana*) in the Sierra Nevada. The foxtail is a rare pine occurring only within California.

Because California's forests play such an important role in the state's economy, environmental function, and well-being of its residents, it is important to monitor forest status and trends over time. To this end, the 1998 Farm Bill provided for the standardization of the FIA program as an annual program; its support was continued by the 2014 Farm Bill.

Forest Resources

Forest Area and Composition

Of California's almost 100 million ac, about a third are forested (31.9 million ac) (fig. 3). California has the highest species richness in the United States, as well as the highest incidence of endemism, with an estimated 15,000 species of plant and animal unique to the state (Chaplin-Kramer et al. 2016). It owes this status to a wide variation in ecosystems that were classified by Bailey et al. (1994) based on precipitation, temperature, land cover, and terrain (fig. 4).

Forests are distributed throughout the state but differ in species composition, stand density, and productivity. The most productive forest lands are located in areas receiving high levels of precipitation—the North Coast, Sierra

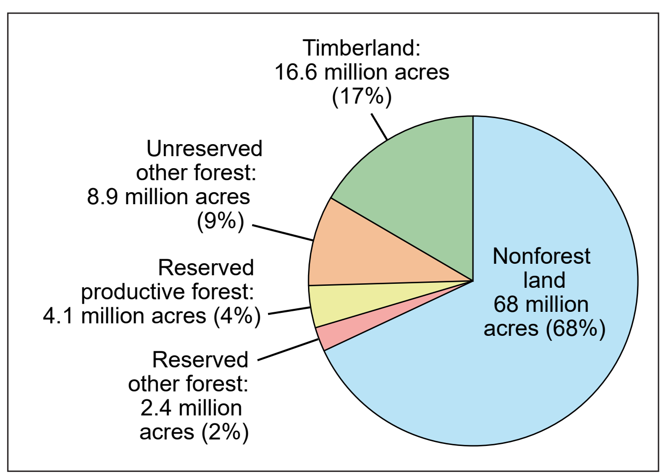


Figure 3—Percentage of forested land by land status in California, 2006–2015.

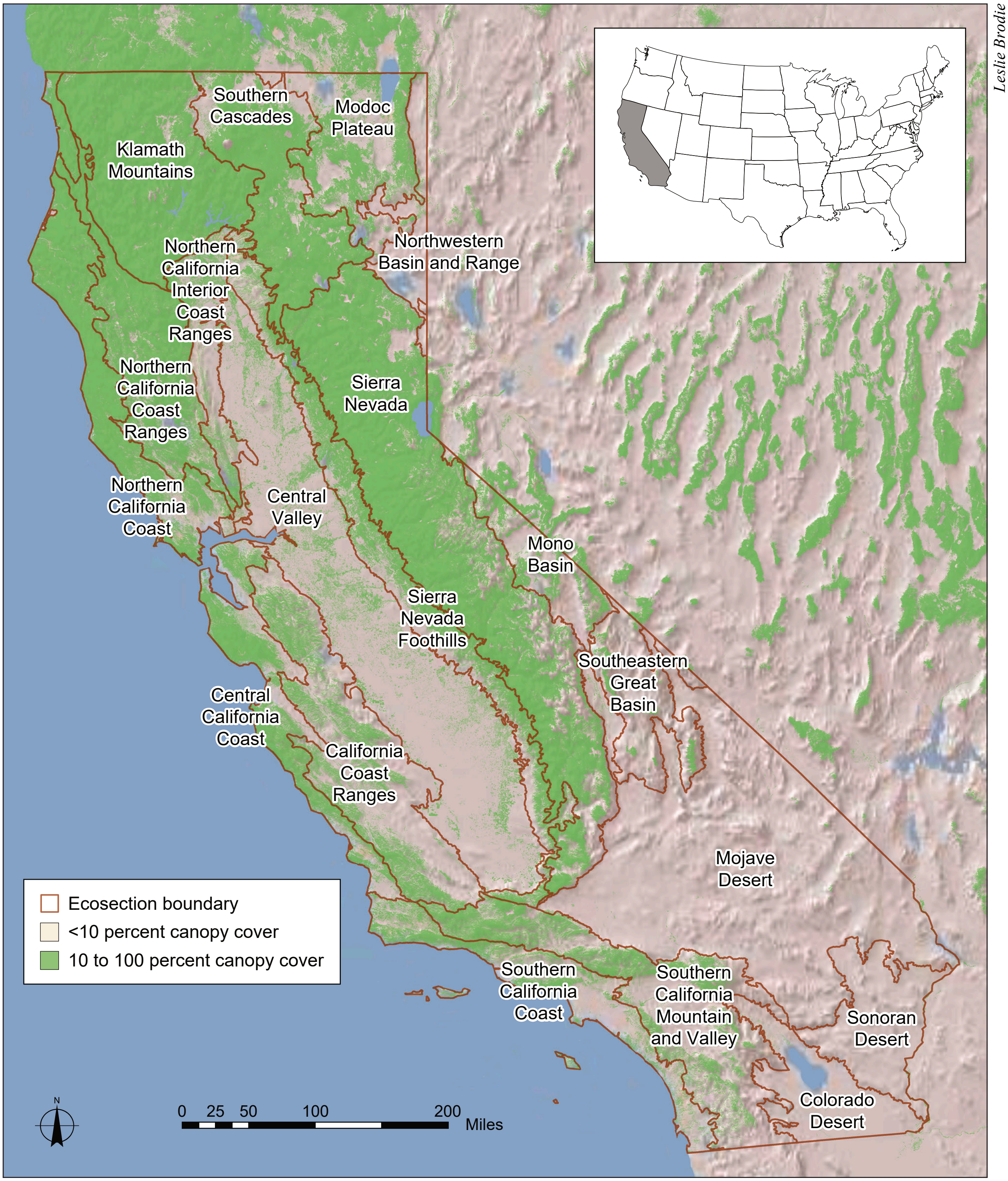


Figure 4—Forested land cover with greater than 10 percent canopy cover (Homer et al. 2011) and ecosections based on precipitation, temperature, land cover, and terrain (Bailey et al. 1994).

Nevada, and Cascade Range regions. Several counties in these areas are more than 75 percent forested—Alpine, Del Norte, Plumas, Sierra, Siskiyou, and Trinity Counties. The Klamath Mountain and Southern Cascade ecoregions, which extend into Oregon, are of global importance in terms of biodiversity, with only five other temperate forest regions worldwide as diverse or with as many endemic species (Olson 2012).

As in many Western States, California's large number of forested acres makes its forestry sector an important part of the state economy. Although the state contains more acres of forest than Oregon and Washington, a much smaller proportion of its forests is classified as timberland: California's forests are 52 percent timberland, while Oregon and Washington are both 80 percent (fig. 5). These differences primarily are the result of the forest types present. The western oak forest type covers more land area than any other forest type in California, yet only 24 percent of it is categorized as timberland. By contrast, the Douglas-fir forest type is the most prevalent in both Oregon and Washington, accounting for more than 90 percent of the timberland in each state.

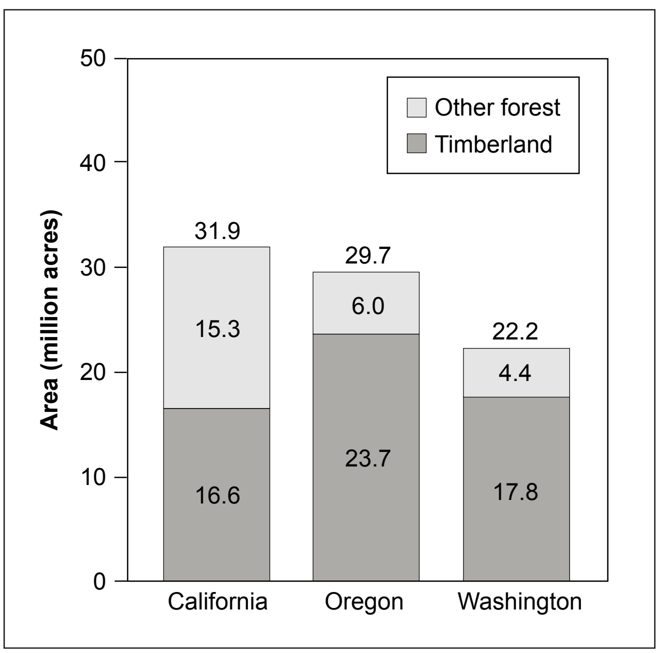


Figure 5—Area of total forested land and timberland in California, Oregon, and Washington, 2006–2015.

Forest type is determined by the predominant species tallied; therefore, it is possible that even a small increase or decrease could trigger a change in forest type classification. The spatial occurrence of forest type groups found on FIA plots in 2006–2015, however, aligns well with Bailey et al.'s (1994) ecosections (fig. 6). The western oak group accounts for the most forest area, 8.9 million ac (table 2), and is found primarily on the margins of the Central Valley and along the Central Coast, making it one of the type groups at greatest risk of encroachment by development (Saving et al. 2001, Wilson 2015). Encroachment by conifer species could also trigger the loss of oak woodlands (Valachovic 2015). Five oak woodland types comprise this diverse group—valley oak woodland, blue oak woodland, blue oak–foothill pine woodland, coastal oak woodland, and montane hardwood forest (University of California 2017). The California mixed-conifer group is the forest type with the second largest area (8.0 million ac) and is also a diverse group; by number of trees (stems) the most abundant species are white fir, Douglas-fir, and incense cedar (fig. 7). Redwood and Douglas-fir types are common on the northern coast, where annual precipitation is greater and coastal fog maintains moisture levels even when precipitation is absent. The fir, spruce, and mountain hemlock group can be found at higher elevations in the Sierra Nevada and Klamath mountains as well as in the southern Cascades and a few places on the Modoc Plateau.

The most abundant hardwood and softwood forest type groups—western oak and California mixed conifer—have substantial proportions of their area in reserved status; 13 percent of western oak and 19 percent of the mixed-conifer group area is reserved (figs. 7 and 8). The forest type group with the lowest percentage in reserved status is western juniper at 9 percent. On the other end of the scale, 86 percent of western white pine's (*P. monticola*) land cover is in reserved status; however, this forest type is not abundant and covers only 171,000 ac.

Stand age is mostly a function of either management or other disturbance event such as a fire, windstorm, or insect outbreak (fig. 9). Silvicultural systems applied in the forest types of California have been varied and depend on management objectives of the owner or land manager. Selection cutting (removing individual or small groups of trees) results in mixed-age stands and was purported to work

Table 2—Area of forest land by forest type group and land status, California, 2006–2015

	Land status													
	Unreserved forests						Reserved forests							
	Timberland		Other forest		Total		Productive		Other forest		Total		All forest land	
Forest type group	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
	Thousand acres													
Softwoods:														
California mixed conifer	6,453.8	156.8	18.8	9.2	6,472.6	157.0	1,492.9	84.1	16.2	10.6	1,509.1	84.6	7,981.7	172.9
Douglas-fir	879.6	68.9	7.4	6.5	886.9	69.2	209.7	35.9	28.8	12.9	238.5	38.1	1,125.4	78.6
Fir/spruce/mountain hemlock	1,378.0	85.0	35.5	14.5	1,413.5	86.1	589.1	57.4	50.9	17.8	640.0	59.8	2,053.4	104.4
Lodgepole pine	306.2	42.0	51.4	17.5	357.6	45.2	441.2	49.6	224.9	37.1	666.2	59.5	1,023.7	74.5
Pinyon/juniper woodlands	10.6	7.6	1,049.3	75.0	1,059.8	75.3	5.8	6.5	477.0	53.3	482.8	53.5	1,542.7	90.9
Ponderosa pine	2,083.5	100.6	41.8	15.1	2,125.3	101.6	215.1	35.0	29.7	12.8	244.7	37.1	2,370.1	107.8
Redwood	650.6	59.4	—	—	650.6	59.4	111.4	25.4	—	—	111.4	25.4	762.0	64.4
Western juniper	190.0	32.6	1,197.4	81.4	1,387.4	87.1	91.7	24.4	43.5	16.6	135.1	29.4	1,522.6	91.8
Western white pine	17.8	9.1	6.0	6.1	23.8	11.0	98.7	24.0	49.0	17.6	147.6	29.8	171.4	31.7
Other western softwoods	101.8	24.4	90.2	22.5	192.0	33.2	49.5	17.3	322.5	43.0	372.0	45.9	564.0	56.5
Total	12,071.8	177.9	2,497.8	111.4	14,569.5	201.3	3,305.1	108.7	1,242.4	80.8	4,547.4	124.6	19,117.0	219.1
Hardwoods:														
Alder/maple	153.0	28.3	20.6	8.1	173.5	29.4	34.9	14.5	10.7	8.0	45.5	16.6	219.1	33.7
Aspen/birch	26.5	11.7	24.2	10.9	50.7	16.0	8.9	6.4	20.6	10.4	29.6	12.2	80.2	20.1
Elm/ash/cottonwood	—	—	21.2	9.4	21.2	9.4	—	—	8.7	6.0	8.7	6.0	29.9	11.1
Tanoak/laurel	1,307.3	83.5	168.0	30.4	1,475.3	88.1	280.4	40.8	93.7	23.9	374.2	46.9	1,849.5	99.1
Western oak	2,087.4	106.9	5,647.8	153.7	7,735.2	179.6	311.4	42.9	865.2	66.8	1,176.7	77.8	8,911.9	192.6
Woodland hardwoods	41.4	15.2	189.5	32.0	230.9	35.4	—	—	34.0	12.4	34.0	12.4	264.9	37.5
Other hardwoods	296.3	40.3	152.5	28.7	448.8	49.3	68.4	21.2	25.4	12.1	93.8	24.3	542.7	55.0
Total	3,911.8	137.5	6,223.9	160.5	10,135.7	198.2	704.1	63.7	1,058.4	73.9	1,762.5	94.2	11,898.2	214.0
Nonstocked	593.2	55.4	135.3	26.6	728.6	61.1	127.5	27.7	70.3	19.6	197.8	33.8	926.3	69.9
All forest types	16,576.8	168.9	8,856.9	187.5	25,433.8	203.3	4,136.6	115.0	2,371.1	107.6	6,507.7	134.3	31,941.5	201.5

Note: Totals may be off because of rounding; data are subject to sampling error; SE = standard error; — = less than 50 ac was estimated.

Leslie Brodie

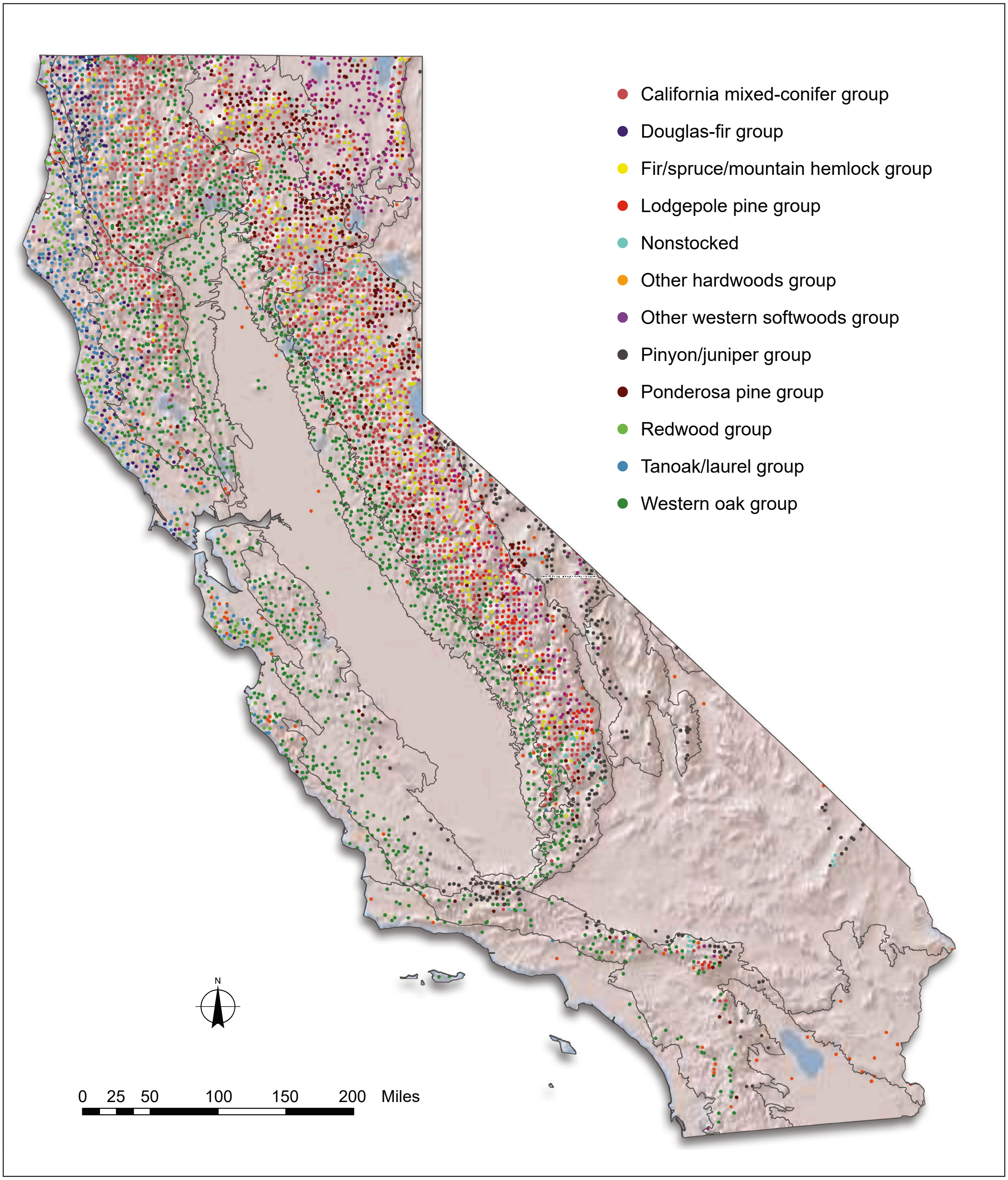


Figure 6—Forested plots inventoried in the period 2006–2015 shown by forest type group. Plot locations are approximate to ensure confidentiality. .

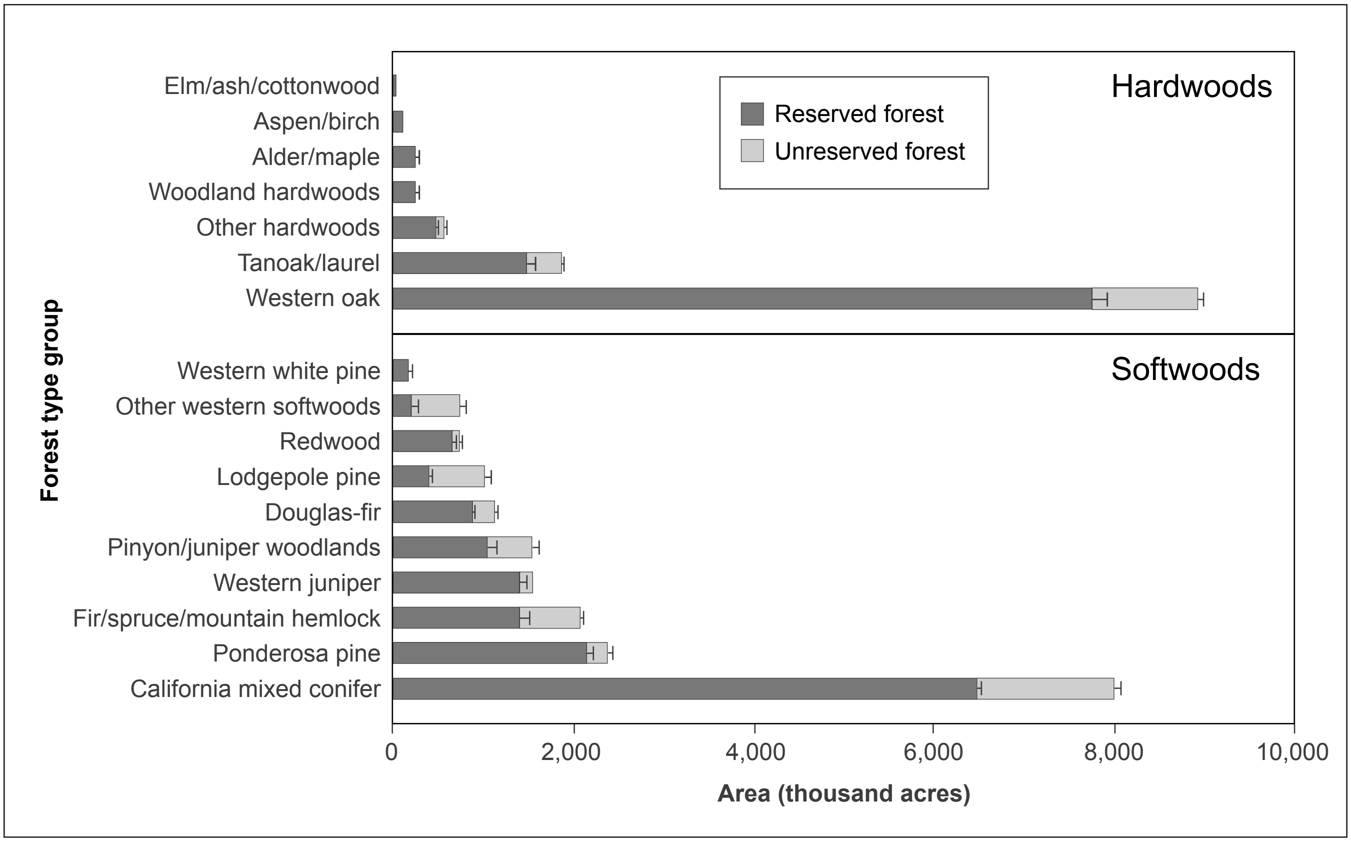


Figure 7—Number of acres of forest land by forest type group and reserved status in California, 2006–2015. The California mixed-conifer group is a diverse group containing white fir (24 percent), Douglas-fir (19 percent), incense cedar (17 percent), ponderosa pine (9 percent), sugar pine (4 percent), other conifers (9 percent), and hardwoods (18 percent).

Gerad Dean

Gerad Dean

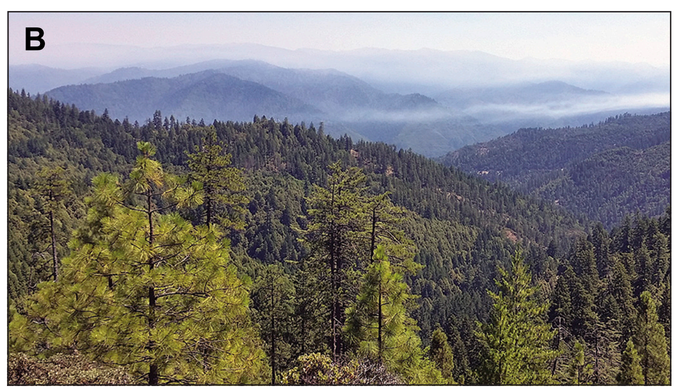
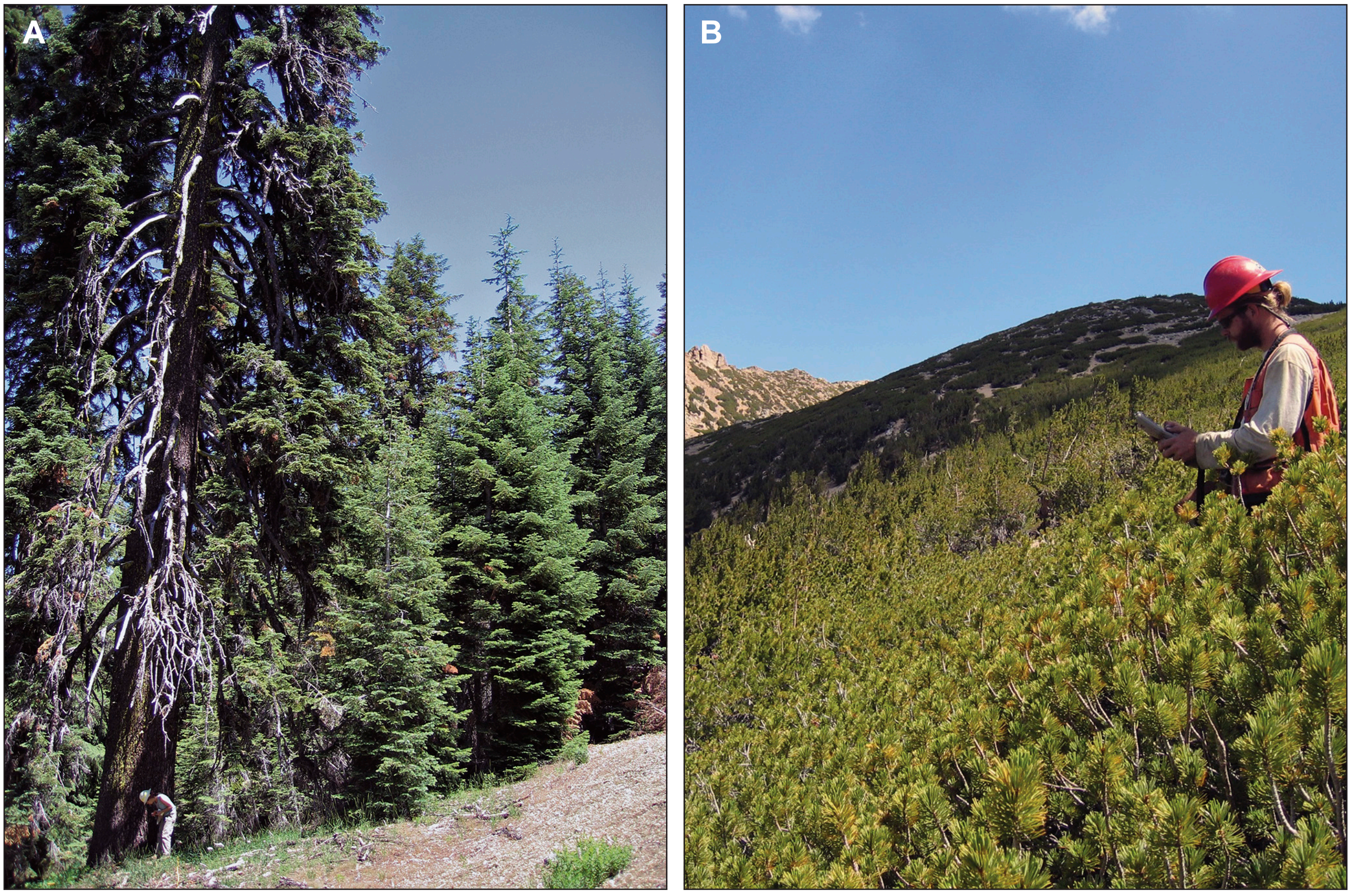


Figure 8—(A) Western oak and (B) California mixed conifer are the two most common forest type groups in California.

Jane Terzibashian



Daniel Coles

Figure 9— (A) Mixed-age stand in Siskiyou County, California, with remnant mature red fir and (B) numerous lodgepole pine seedlings resulting from a stand-replacing disturbance.

well in the mixed-conifer forests of the Sierra Nevada in the 1920s (Dunning 1923). Both clearcutting (which results in even-aged stands) and selection cutting have been used in California's mixed-conifer forest types (Youngblood 2005). Natural regeneration (relying on remaining seed trees) was the predominant regeneration method used (Stewart et al. 2016) until passage of the 1973 California Forest Practices Act, which required replanting where conifers were harvested (Valachovic 2015). Although it is often difficult to ascertain stand origin on FIA plots, 1.5 million ac of forest in the ponderosa pine type are estimated to have originated from natural regeneration as compared to only 0.5 million ac originating from planting. For several hardwood species, stand reestablishment via sprouting from stumps has been demonstrated to be an effective approach (McDonald and Tappeiner 1996).

Silvicultural systems in recent years have become more complex as managers are increasingly expected to manage each stand to achieve multiple objectives, for example, timber production, wildlife habitat, biodiversity, and water quality (Tappeiner et al. 2007). The combination of different silvicultural systems, management objectives, and the often patchy distribution of natural disturbances has resulted in a wide variety of forest structures across the landscape. Stand age on FIA plots is estimated by taking an increment core sample from two or three trees in the dominant diameter class and counting the rings. Although stand age may be a useful concept for even-aged stands, its utility in stands with a more complex age structure is often less clear (Stevens et al. 2016).

The following tabulation (see fig. 7) gives the approximate percentage of each species in the California mixed-conifer group:

Percentage of live stems

	Percent
White fir	24
Douglas-fir	19
Incense-cedar	17
Ponderosa pine	9
Sugar pine	4
California red fir	3
Jeffrey pine	3
Lodgepole pine	2
Other conifers	1
Hardwoods	18

The age class of the dominant trees in the principal forest types sampled by FIA plots shows that older stands are more likely to be coniferous forest types than hardwood types (fig. 10). For both hardwoods and softwoods, the mean number of acres has remained fairly constant from 2010 to 2015, and the largest proportion of forested land area is covered by trees in the middle age classes—41 to 120 years old (fig. 10). Softwoods, however, also have a large number of acres in the 201+ years age class. This class consists primarily of the California mixed-conifer type and, as a distant second, the fir/spruce/mountain hemlock forest type (fig. 11). Of the area that is covered by forests 201+ years old, 80 percent is managed by the Forest Service (2.1 million ac) (fig. 12).

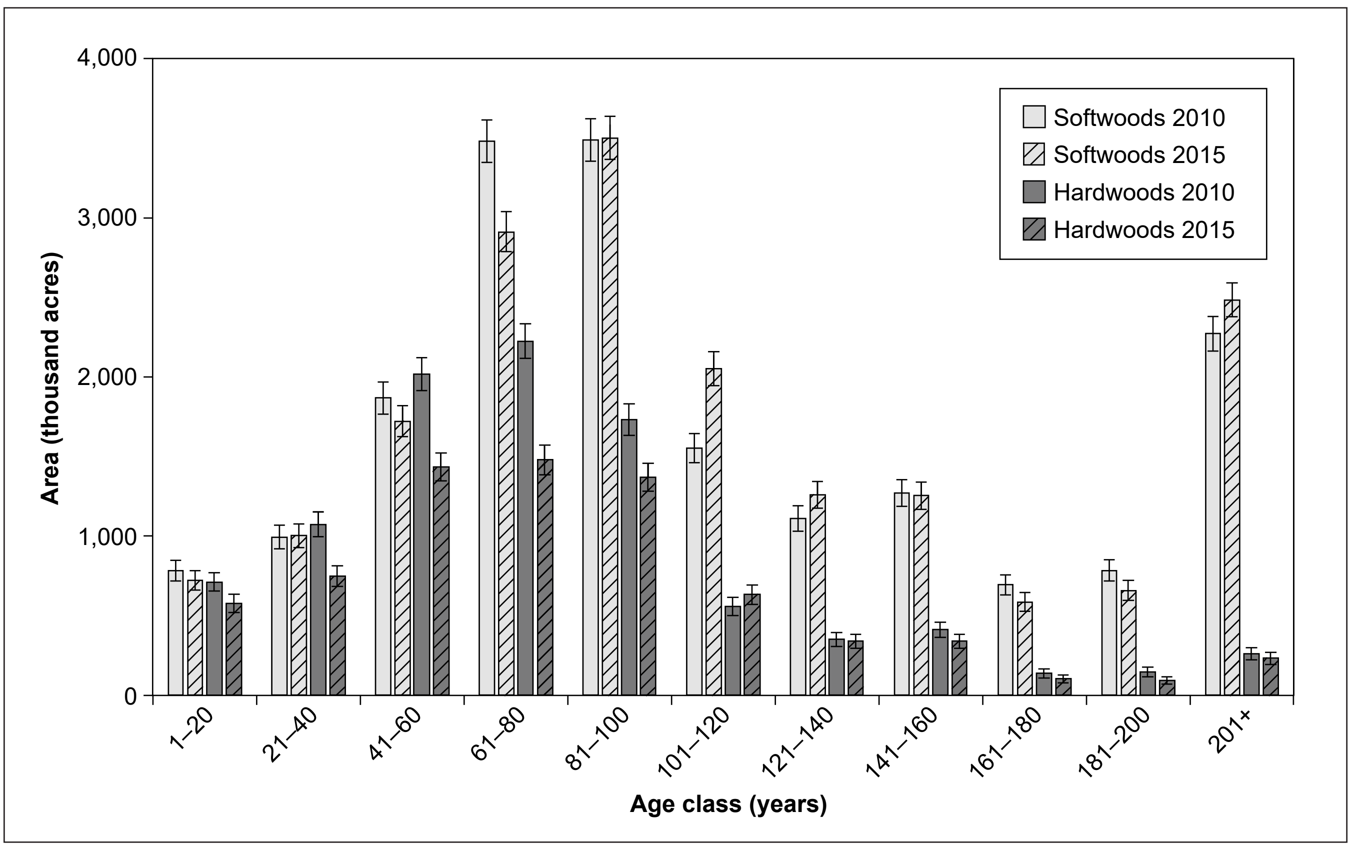


Figure 10—Area of forested land by age class of the dominant species type 2001–2010 and 2006–2015 (see "Forest Inventory and Analysis—An Overview" section for explanation of measurement cycles).

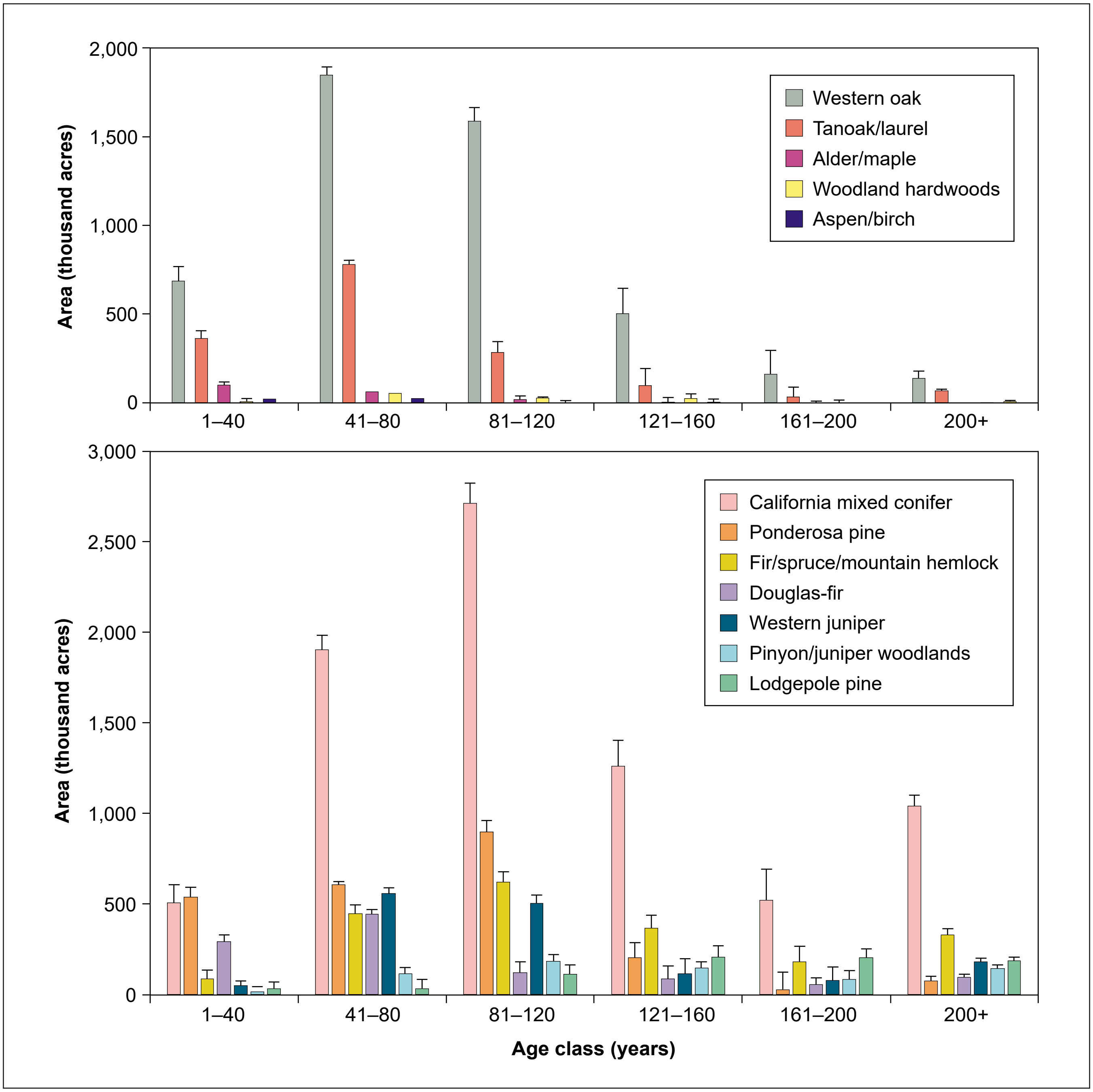


Figure 11—Area of forest land by age class for the most common hardwood and softwood forest types, California, 2006–2015.

Forest Ownership

Management objectives and level of intensity are dependent on both specific site conditions and forest ownership. The Forest Service manages most publically owned forest land in California—48 percent of total forested acres (15.3 million ac) (table 3). The Multiple-Use Sustained-Yield Act of 1960 stipulates that national forests be managed for multiple uses including "outdoor recreation, range, timber, watershed, and wildlife and fish" (Public Law 86-517). Other public lands are managed for different and sometimes narrower objectives, such as preservation and recreation

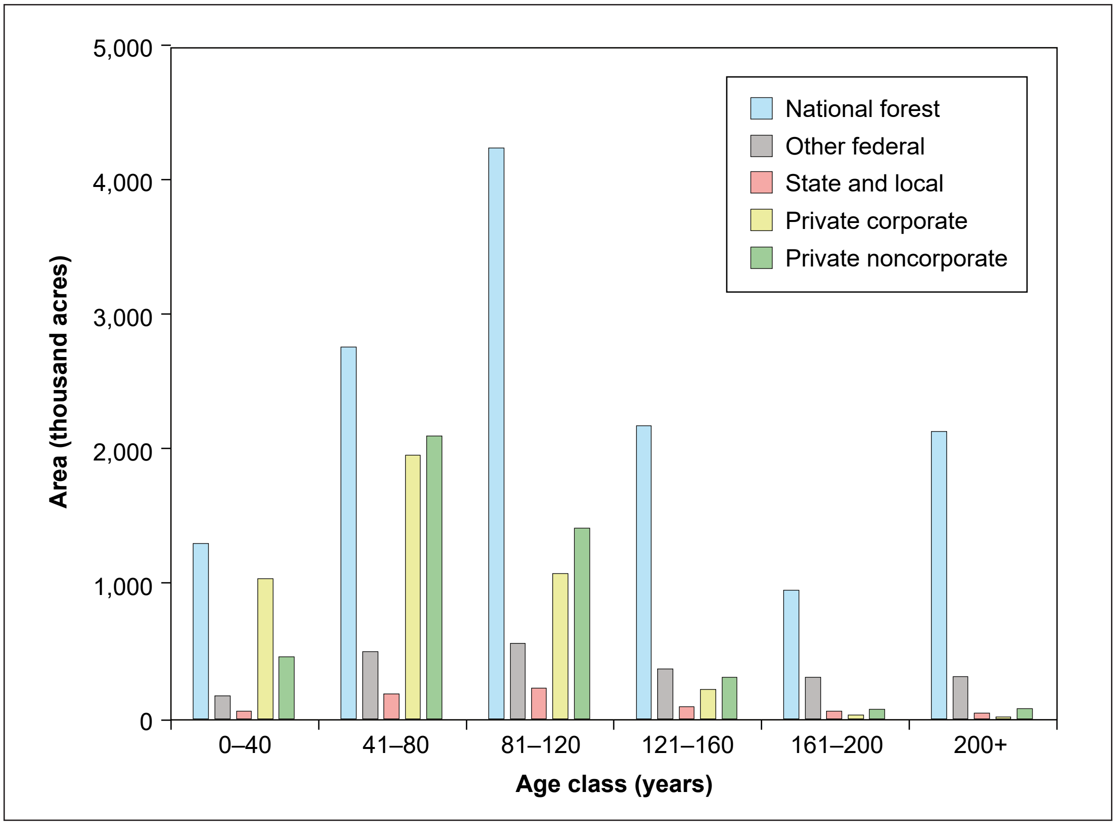


Figure 12—Area of forest land by age class and ownership, California, 2006–2015.

(National Park Service) and conservation of wildlife habitat (California Department of Fish and Wildlife). Privately owned land can be subject to a variety of management objectives. Family (noncorporate) owners often typically place more weight on amenity-related objectives such as beauty, wildlife, and nature protection (Butler et al. 2016). Larger (and corporate) private landholdings that are managed with financial objectives are often owned by either industrial forest management organizations or are held by real estate investment trusts and timber investment management organizations.

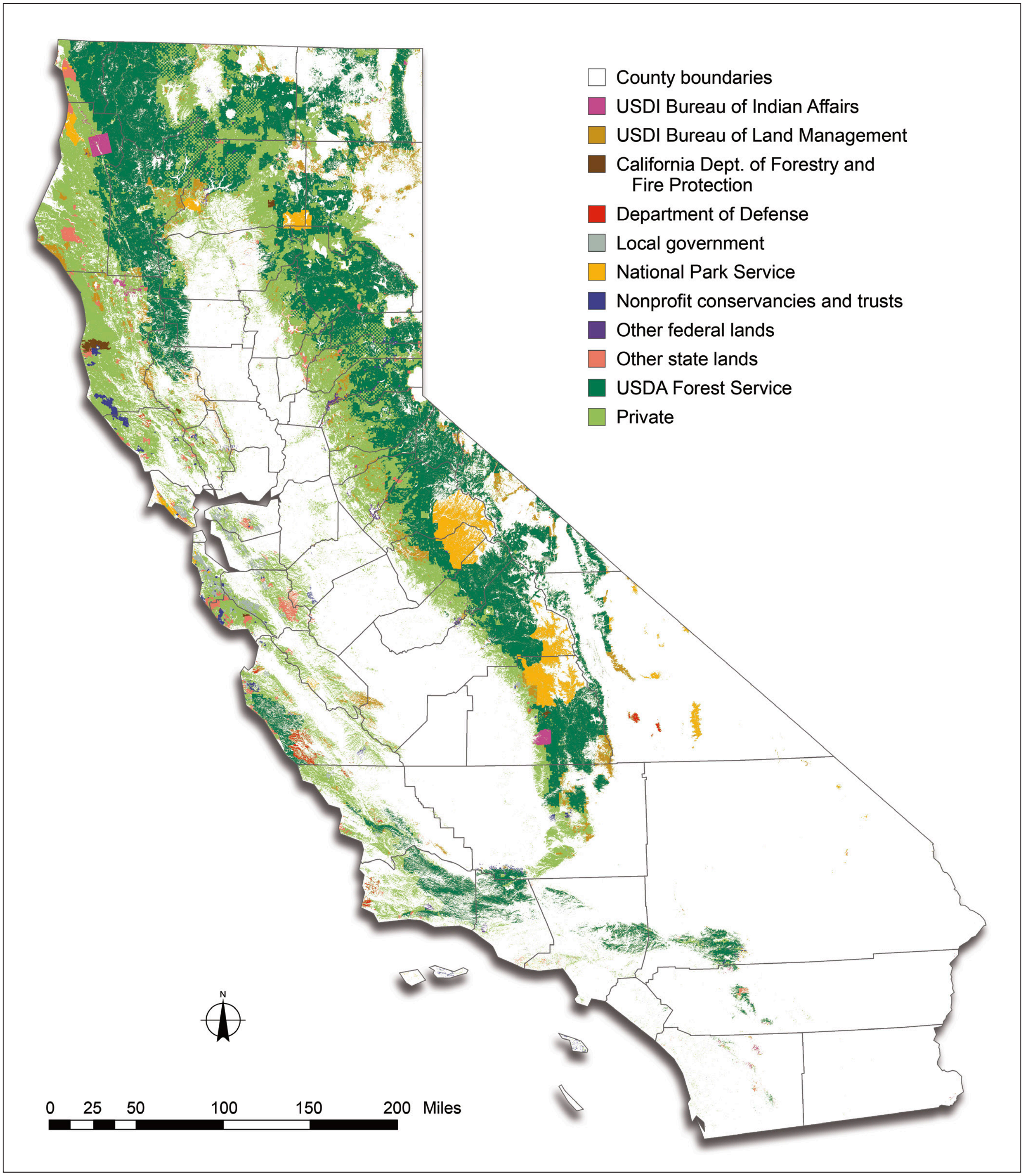
Private land ownership is greatest along the north coast and interior sites (where site quality is high) and on the central valley margins, where western oak woodlands are common (fig. 13). Although the Forest Service manages the greatest area of forest in the state, much of it is at higher elevations and is categorized as being within the less productive site classes—54 percent of forests administered by the Forest Service produce less than 85 ft/ac/year (site classes V+), while 12 percent are highly productive (site classes I through IV), capable of producing 165+ ft/ac/year if fully stocked. Private corporate forests have an altogether different productivity profile—only 9 percent of their holdings are on less productive sites, and 53 percent are site class IV and better (fig. 14).

Forests managed by the Forest Service and by corporations each have about one-third of holdings in the California mixed-conifer type (34 percent and 32 percent, respectively). The Forest Service, however, because of the generally higher elevation of its lands, has a greater percentage of the fir/spruce/mountain hemlock type, while private corporations have a greater percentage in the tanoak/laurel type. The vast majority of private, noncorporate forest lands (59 percent) are of the western oak forest type. These are the forested areas at greatest risk of conversion to other land use types (agricultural or urban) as population increases (Wilson 2015).

Table 3—Area of forest land by ownership and land status, California 2006–2015

	Land status													
	Unreserved forests						Reserved forests							
	Timberland		Other forest		Total		Productive		Other forest		Total		All forest land	
Ownership	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
	Thousand acres													
U.S. Forest Service:														
National forest	8,870.6	120.8	2,439.7	99.6	11,310.3	120.5	2,781.7	90.6	1,231.0	76.0	4,012.8	93.2	15,323.1	122.0
Other federal government:														
Bureau of Land Management	297.3	41.7	931.8	69.4	1,229.1	79.9	50.2	17.5	211.5	35.5	261.8	39.7	1,490.9	86.0
Departments of Defense or Energy	13.3	9.0	71.9	20.3	85.3	22.2	—	—	5.5	5.7	5.5	5.7	90.7	22.9
National Park Service	—	—	—	—	—	—	972.0	60.4	462.1	51.6	1,434.2	75.7	1,434.2	75.7
U.S. Fish and Wildlife Service	—	—	—	—	—	—	3.6	3.7	0.6	0.6	4.2	3.7	4.2	3.7
Other federal	—	—	106.7	24.8	106.7	24.8	—	—	14.0	8.5	14.0	8.5	120.7	26.2
Total	310.6	42.4	1,110.4	74.9	1,421.0	85.0	1,025.9	61.6	693.7	61.0	1,719.6	81.2	3,140.6	100.2
State and local government:														
Local	49.0	16.9	115.1	24.6	164.2	30.1	38.4	14.3	167.1	29.7	205.5	31.7	369.7	43.3
State	94.5	22.3	43.5	15.9	138.1	27.0	285.7	33.4	273.4	37.8	559.1	48.1	697.1	47.8
Other public	—	—	8.6	7.1	8.6	7.1	4.9	5.5	5.9	6.4	10.8	8.4	19.4	11.0
Total	143.6	27.8	167.2	30.2	310.8	40.9	329.0	36.0	446.3	46.1	775.4	54.7	1,086.2	60.8
Corporate private	4,248.6	121.6	772.1	65.2	5,020.7	134.4	—	—	—	—	—	—	5,020.7	134.4
Noncorporate private:														
Nongovernmental conservation or natural resource organizations	255.6	39.7	131.3	27.2	386.8	48.1	—	—	—	—	—	—	386.8	48.1
Unincorporated partnerships, associations, or clubs	134.7	28.7	70.5	19.0	205.2	34.6	—	—	—	—	—	—	205.2	34.6
American Indian	177.7	32.9	68.6	20.6	246.3	38.7	—	—	—	—	—	—	246.3	38.7
Individual	2,435.5	107.4	4,097.1	129.8	6,532.6	158.2	—	—	—	—	—	—	6,532.6	158.2
Total	3,003.4	115.7	4,367.5	132.6	7,370.9	163.9	—	—	—	—	—	—	7,370.9	163.9
All private	7,252.0	119.6	5,139.6	140.0	12,391.6	153.2	—	—	—	—	—	—	12,391.6	153.2
All owners	16,576.8	168.9	8,856.9	187.5	25,433.8	203.3	4,136.6	115.0	2,371.1	107.6	6,507.7	134.3	31,941.5	201.5

Note: Totals may be off because of rounding; data are subject to sampling error; SE = standard error; — = less than 50 ac was estimated.



Leslie Brodie

Figure 13—Land ownership in California, 2013 (CAL FIRE 2013). Publically owned land in California is managed by several agencies; the U.S. Forest Service manages the largest portion—48 percent of all forested land.

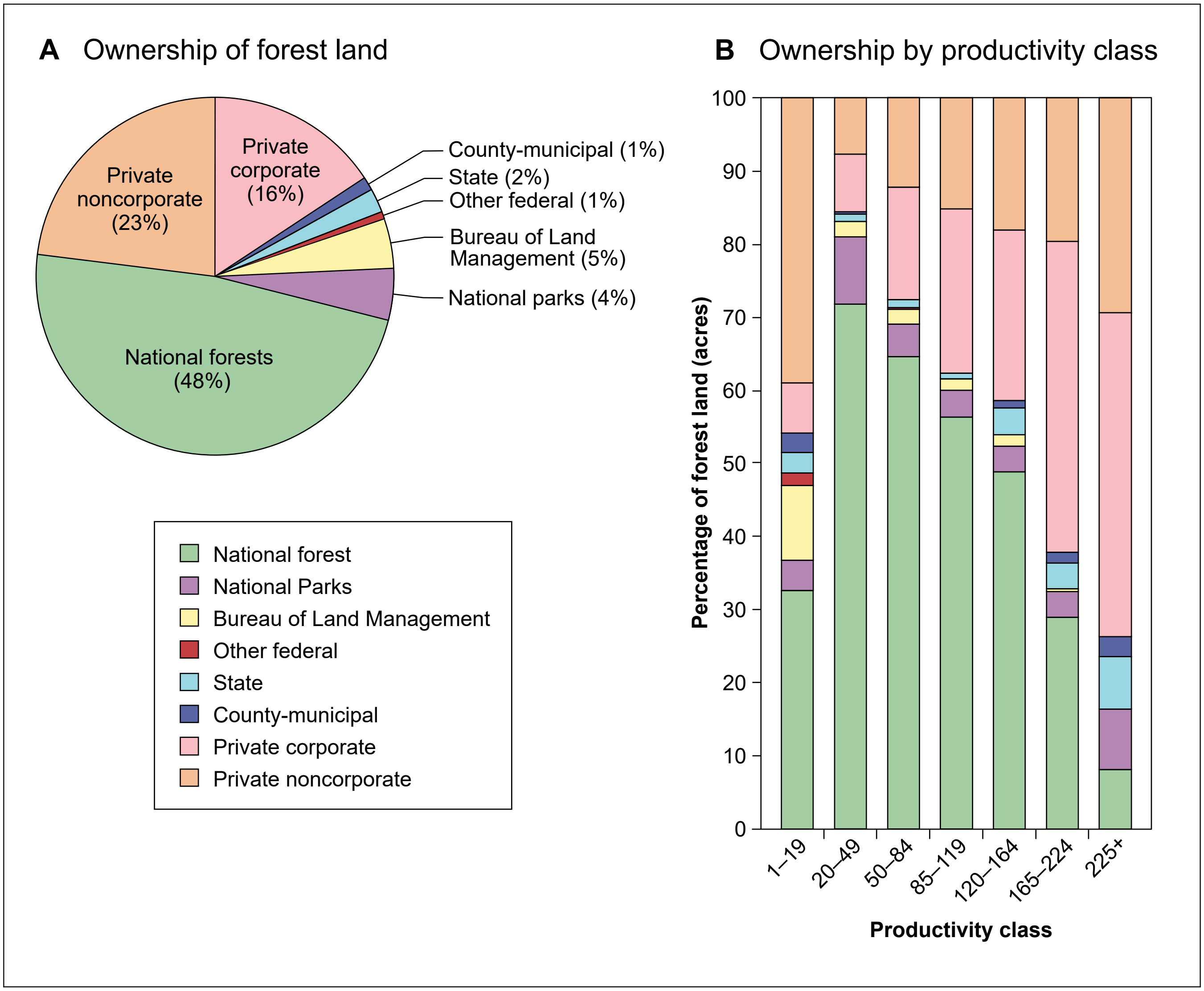


Figure 14—(A) Ownership of timberland in California, and (B) productivity class of forest land by owner in California, 2006–2015.

Forest Volume

Tree volume calculations rely on height and diameter measurements taken by field crews, volume equations specific to the area, forest type, and species (Zhou and Hemstrom 2010). Volume estimations are useful not only for estimating productivity in terms of merchantable wood, but when adjusted for the specific gravity of a species (Ross 2010), volume can also be used to estimate carbon storage. Both productivity and carbon storage are discussed in subsequent sections.

As in most forests, there is a much greater number of smaller trees than larger trees in the California landscape. California forests contain an estimated 1.77 billion oak seedlings, 940 million tanoak seedlings, and 850 million true fir (mainly white and red fir) seedlings, but their volume is minimal, and most die long before reaching mature size. For most conifer species, the 17- to 21-inch diameter class contains the greatest volume; for hardwood species, the 9- to 13-inch class contains the greatest volume. Although trees in the larger diameter classes have more volume per tree, there are progressively fewer trees in these classes (fig. 15).

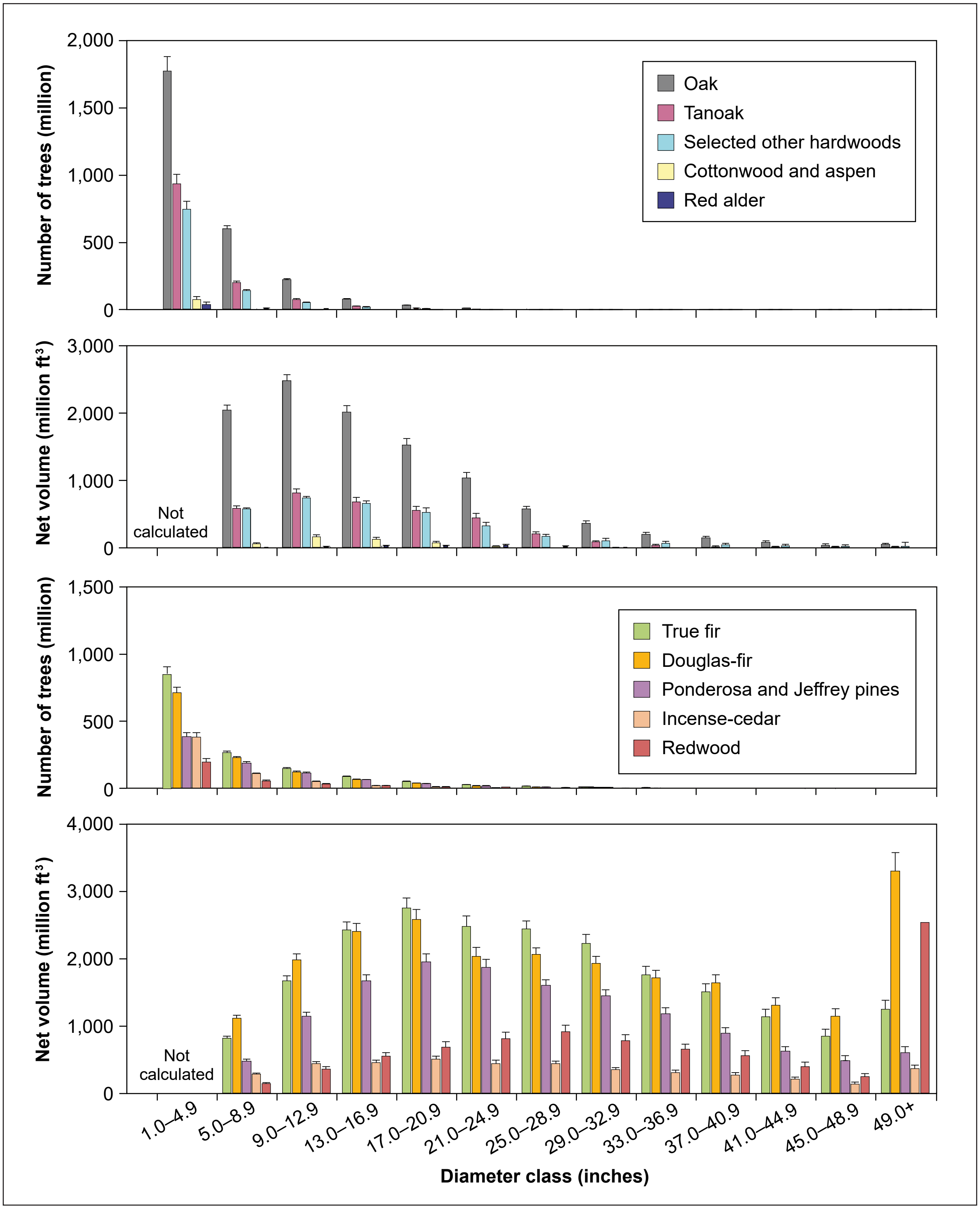


Figure 15—Number and net volume of major species groups by diameter class, California, 2006–2015. Although small trees are very numerous, most of the volume is contained within the middle diameter classes.

Four coniferous forest types contain the greatest volume per acre—redwood (11,256 ft), Douglas-fir (6,164 ft), fir/spruce/mountain hemlock (5,755 ft) and California mixed conifer (4,904 ft) (fig. 16). These forest types can grow in dense stands and may contain large individuals supporting a high amount volume in a small area (fig. 17). However, some of these forest types cover a relatively small area. The species groups with the most live-tree volume are the true firs, Douglas-fir, and ponderosa/Jeffrey pines (233, 214, and 140 billion board feet, respectively). Most of the hardwood volume is contained within oaks (106 billion board feet).

The stands with the greatest volume per acre can be found along the northern California coast, in the Klamath Mountains, the southern Cascade Range, and the Sierra Nevada. Nearly 70 percent of live-tree volume (70.3 billion board feet) is on publically owned land, and most of this falls within national forests (table 4). About a third of the volume on federal and state forests is in reserved status in parks and wilderness areas, where active management for timber production is not an option (fig. 18).

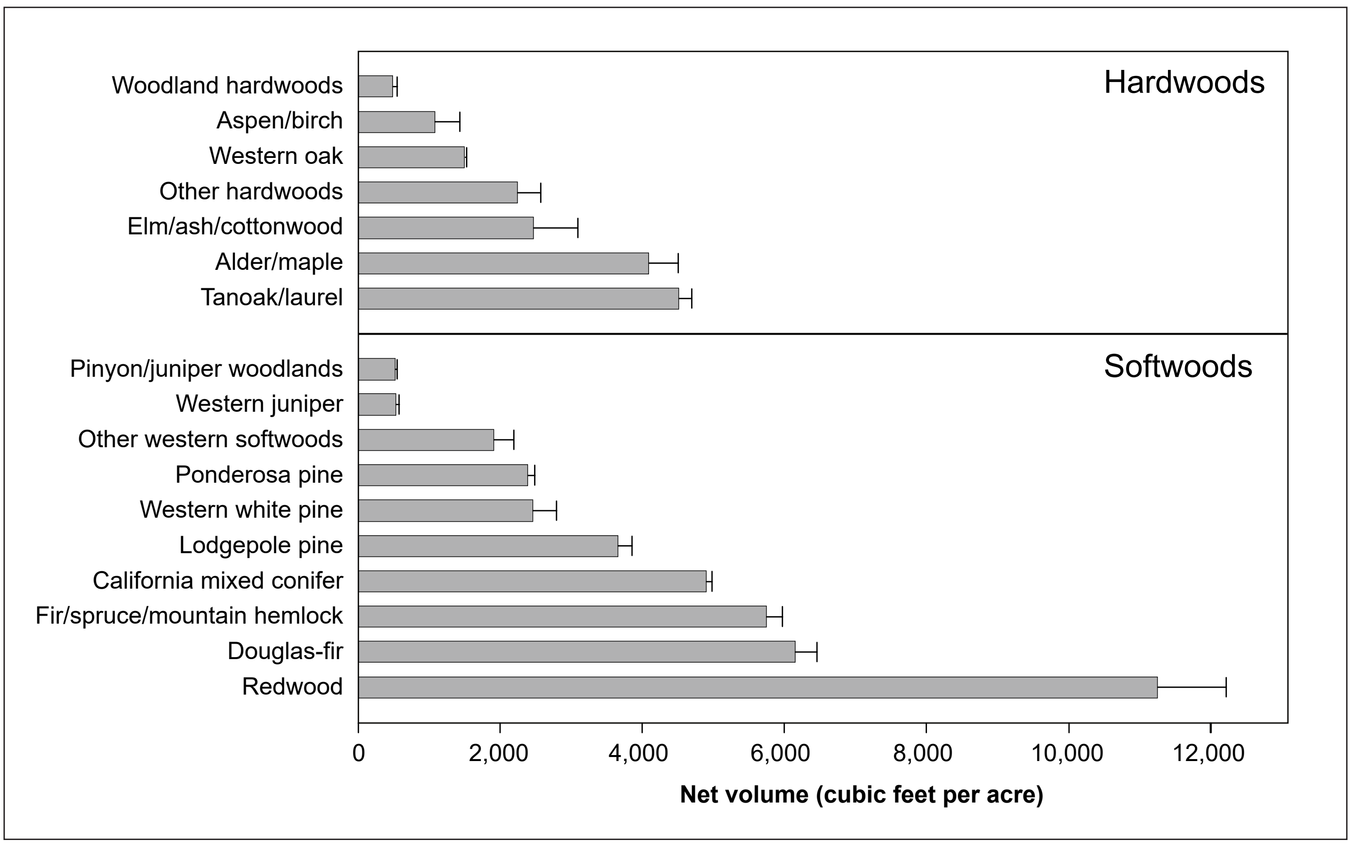


Figure 16—Average net volume per acre by forest type, California, 2006–2010.

Lindsey Salmonson

Figure 17—The redwood forest type is capable of encompassing the greatest volume per acre of any forest type in California—more than 11,000 ft per acre.

Table 4—Area of forest land by ownership and land status, California 2006–2015

	Land status													
	Unreserved forests						Reserved forests							
	Timberland		Other forest		Total		Productive		Other forest		Total		All forest land	
Ownership	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
	Thousand acres													
U.S. Forest Service:														
National forest	38,697.6	838.1	2,256.6	177.2	40,954.2	820.7	13,420.9	642.9	1,519.5	163.2	14,940.4	636.1	55,894.6	945.4
Other federal government:														
Bureau of Land Management	1,099.0	219.5	514.6	70.4	1,613.6	228.9	245.3	94.9	139.5	31.9	384.8	100.1	1,998.4	247.4
Departments of Defense or Energy	21.1	16.5	66.3	24.8	87.4	29.8	—	—	8.4	8.6	8.4	8.6	95.7	31.0
National Park Service	—	—	—	—	—	—	6,317.7	581.4	637.5	124.5	6,955.2	588.9	6,955.2	588.9
U.S. Fish and Wildlife Service	—	—	—	—	—	—	2.9	2.9	1.3	1.3	4.1	3.2	4.1	3.2
Other federal	—	—	40.8	12.3	40.8	12.3	—	—	5.3	2.9	5.3	2.9	46.1	12.6
Total	1,120.1	219.9	621.7	75.2	1,741.8	230.7	6,565.9	584.1	791.8	126.8	7,357.8	590.7	9,099.6	599.2
State and local government:														
Local	243.6	100.6	175.7	47.9	419.3	112.2	353.5	143.1	261.0	60.4	614.5	152.1	1,033.8	188.5
State	811.2	215.6	43.9	28.1	855.1	215.1	3,016.8	679.5	377.1	100.5	3,393.9	683.9	4,249.0	645.0
Other public	—	—	2.7	2.5	2.7	2.5	34.1	38.0	1.8	1.9	35.9	38.0	38.6	38.1
Total	1,054.8	236.9	222.3	55.6	1,277.1	241.7	3,404.4	693.4	639.9	115.7	4,044.3	698.3	5,321.4	666.1
Corporate private	14,678.5	595.3	893.9	101.5	15,572.4	600.2	—	—	—	—	—	—	15,572.4	600.2
Noncorporate private:														
Nongovernmental conservation or natural resource organizations	733.0	135.6	83.8	21.4	816.9	137.3	—	—	—	—	—	—	816.9	137.3
Unincorporated partnerships, associations, or clubs	665.3	167.7	102.0	33.8	767.3	171.4	—	—	—	—	—	—	767.3	171.4
American Indian	1,014.9	234.4	43.7	21.5	1,058.6	235.2	—	—	—	—	—	—	1,058.6	235.2
Individual	10,700.4	619.1	4,105.6	194.9	14,806.0	632.6	—	—	—	—	—	—	14,806.0	632.6
Total	13,113.7	667.7	4,335.1	198.1	17,448.8	677.9	—	—	—	—	—	—	17,448.8	677.9
All private	27,792.2	730.7	5,229.0	216.5	33,021.2	722.3	—	—	—	—	—	—	33,021.2	722.3
All owners	68,664.7	1,133.4	8,329.6	293.9	76,994.3	1,114.0	23,391.1	1,110.3	2,951.3	236.6	26,342.4	1,112.6	103,336.7	1,424.1

Note: Totals may be off because of rounding; data are subject to sampling error; SE = standard error; — = less than 50,000 ft was estimated.
[a] Includes all live trees ≥5 inches in diameter at breast height, consisting of growing-stock, rough-cull, and rotten-cull tree classes.

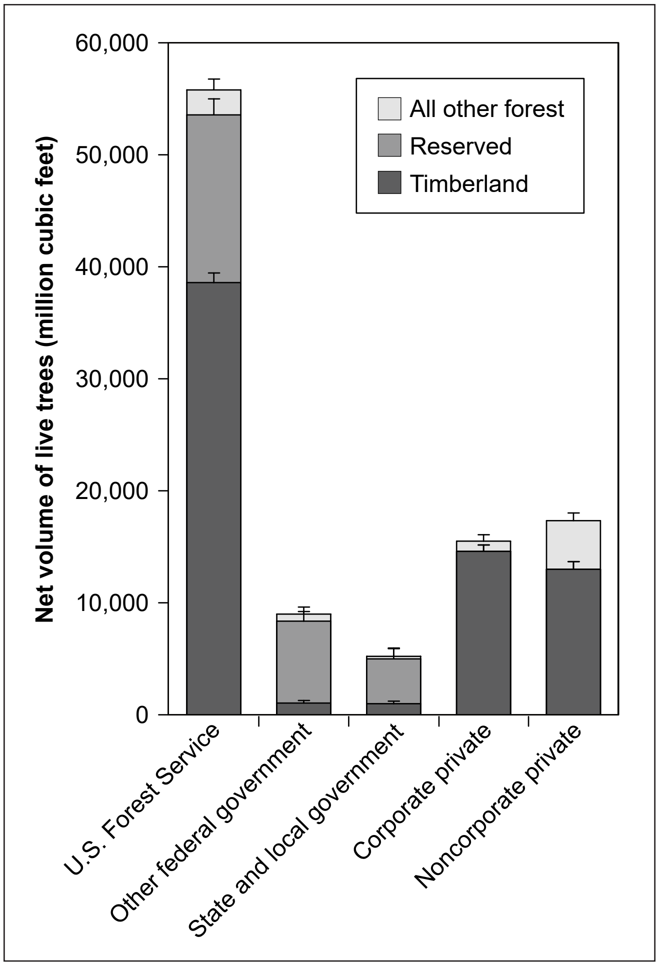


Figure 18—Net volume of live trees by ownership, California, 2006–2015. Although the majority of standing live tree volume is managed by the U.S. Forest Service, more than 30 percent of it is in reserved status.

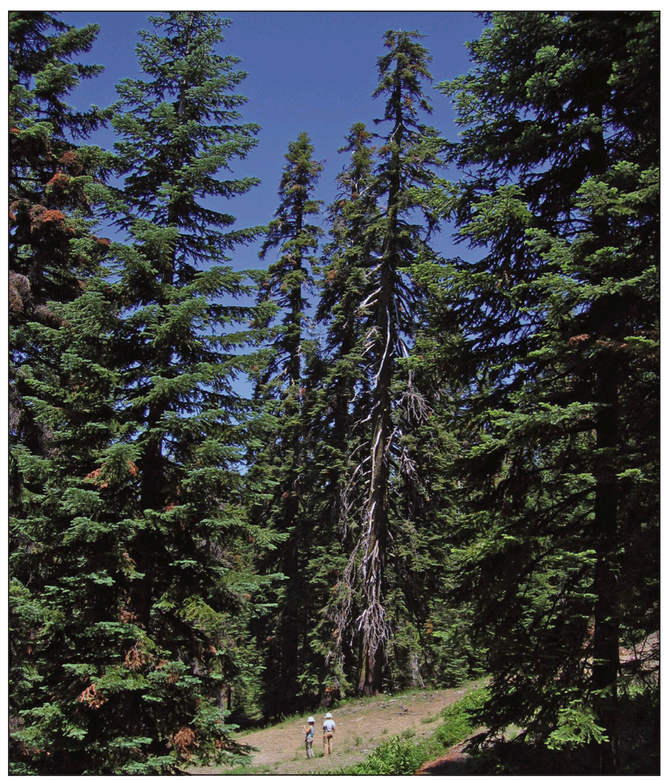
Forest Biomass and Carbon Storage

Glenn Christensen

Estimates of biomass and carbon storage are closely tied to estimates of tree volume but can be expressed in ways that account for all woody tree parts, not just merchantable boles. They can also be combined with or compared to values associated with other types of vegetation such as understory shrubs. Summaries of this type can yield statewide estimates of carbon sequestered by all vegetation and aid in the understanding of how it is distributed, responds to management, and changes over time. Forest type, stand age, and ownership are some of the factors that determine variations in biomass and carbon storage. Biomass depends on both volume and the specific gravity of the wood. Specific gravity, in turn, varies by species, and, for dead wood, by decay class. Net carbon flux between terrestrial and atmospheric carbon pools can help us understand whether a forest is acting as a net sink (sequestering carbon) or a net emitter (releasing carbon), and the magnitude of that sink or emission.

The distribution of aboveground live tree biomass and carbon in California closely tracks the distribution of tree volume described earlier. Most is in the regions with the greatest proportion in forest land—along the north coast and in the Sierra Nevada. The four northwestern counties of Humboldt, Mendocino, Siskiyou, and Trinity collectively contain some of the largest trees in the state and account for 40 percent of all live tree biomass (fig. 19). Live tree boles contain 57 percent of all wood carbon in California (fig. 20).

Aboveground biomass is considered to be the accumulated oven-dry weight of the stem, bark, and branches of live and dead standing trees and down wood on forest land.



Jon Williams

Figure 19—The majority of aboveground biomass in California's forests is in live standing conifer trees such as these red fir in Siskiyou County.

Leslie Brodie

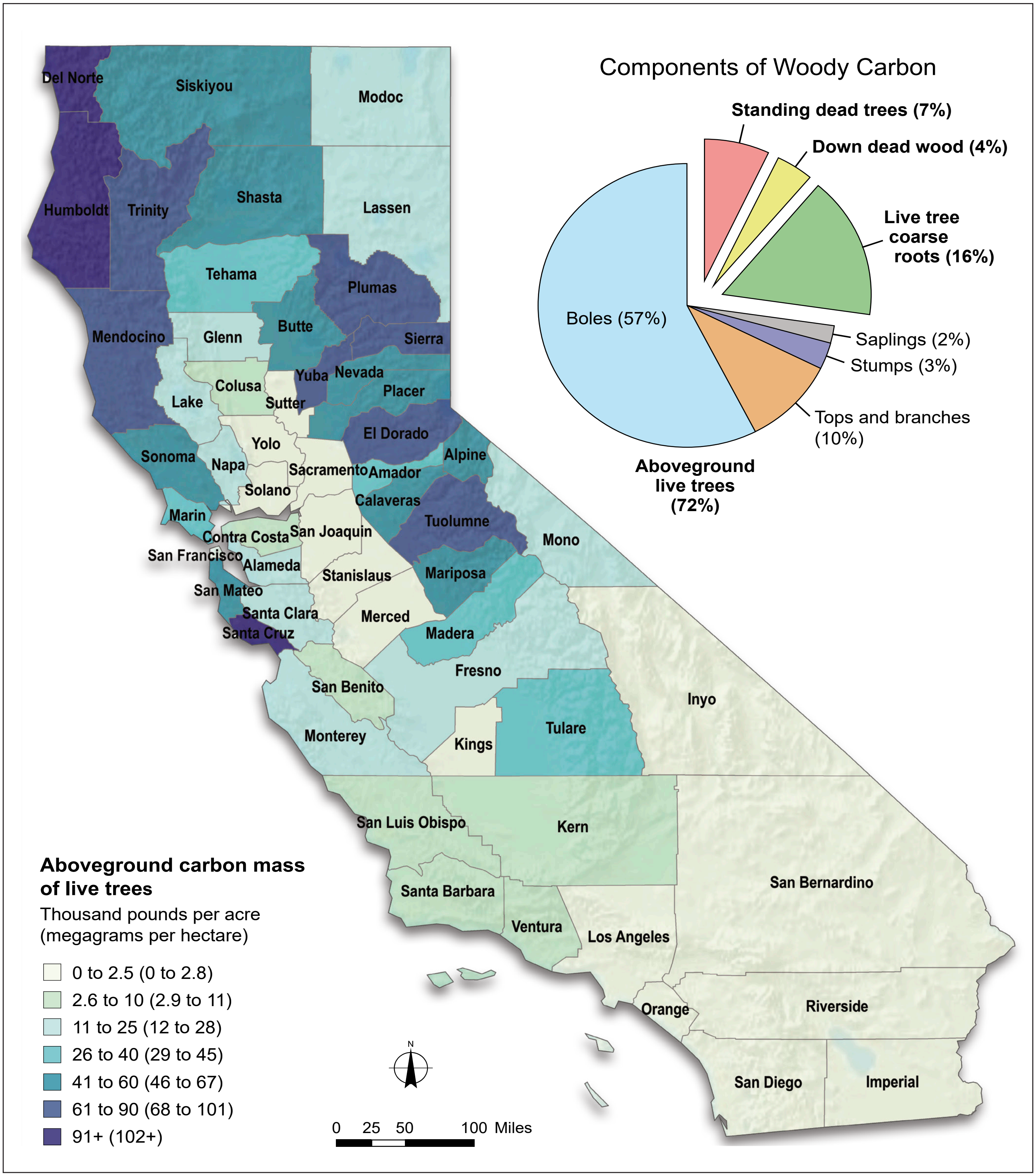


Figure 20—(A) Components of woody carbon and (B) mean aboveground, live tree carbon density by county, California 2006–2015. Forests of the north coast counties currently have the greatest aboveground concentration of live tree carbon in the state.

The total estimated aboveground biomass in California is 2.7 billion tons (2.3 billion Mg). It does not include foliage, cones, fruits, and roots. The estimated carbon stored in the aboveground biomass is approximately half this amount—1.4 billion tons (1.2 billon Mg). Aboveground live trees store the majority of the carbon in this pool, approximately 72 percent (fig. 20A), estimated at 1.1 billion tons (1.0 billion Mg) (table 5). Carbon stored in other pools such as coarse and fine roots, understory vegetation, and organic soil is not included in this estimate.

The statewide mean density of carbon in aboveground wood is 17 tons per acre (39 Mg per hectare, fig. 20). Most (54 percent) of the carbon in aboveground wood can be found on forest land managed by the Forest Service, with 33 percent in private ownerships, and 13 percent within forests administered by other federal, state, and local government agencies (fig. 21).

Carbon density differs among ownership groups, most likely because of differences in management, disturbance histories, site quality, and forest type (fig. 21). Forests administered by the Forest Service and state and local governments have sequestered the most carbon per acre, most likely owing to sizable proportions of these ownerships being in reserved status and not managed for timber production (fig. 18). On average, forests in private ownership contain lower carbon stores. The forest products created from harvested wood are also part of the overall carbon balance, but are not addressed here. About 20 percent of carbon stored in all live trees is found in the oldest stands, those 180 years old and older (fig. 22), which account for only 11 percent of the California's forest area.

Forest Productivity

Timber Resources

FIA defines productive forest land as that which is capable of producing greater than 20 ft per acre per year of wood at culmination of mean annual increment (MAI). Some areas of productive forests are withdrawn from consideration for management of wood products by law or statute (examples include the national wilderness system, and national and state parks) and are designated as "reserved." The reserved status does not apply to private lands; however, restrictions such as logging adjacent to riparian areas apply according to the California Forest Practice Act (CAL FIRE 2016a), but are not considered in this report.

Fluctuations in net volume of growing stock over long periods of time can be influenced by many factors, including conversion of forest to other land uses, changes in harvest intensity, and large-scale disturbances such as wildfires (fig. 23). Growing stock volumes in California have generally been increasing since the late 1970s. This increase is likely attributable to diminishing harvest intensity and the age-class structure of these forests (fig. 11). There have been dramatic shifts in management focus since the mid-1900s, especially on public land. Timber harvest levels in the years following World War II reflected the desire to meet demand for forest products generated by a housing boom and public policies that prioritized stabilization of rural communities. Later in the century, the focus of public land managers shifted from timber production to increasing the amount of older stands and diversifying forest products to include ecosystem services and social values (Davis et al. 2017). Passage of the Northwest Forest Plan (1994), which brought about an abrupt change in management of federal forests in the more productive moist-forest types of the state, formally allowed for harvest of up to 20 percent of previous levels; however, actual harvest levels were closer to 10 percent (Haynes et al. 2017). Examination of the current age-class distribution shows that one-third of stands are younger than 80 years old—many would have "grown into" the minimum 5-inch diameter class (the minimum of what is considered growing stock), within the last 40 years.

Of lands that are unreserved and productive enough to be classified as timberland, lands held by state and local government have the most volume of sawlogs per acre—38.4 thousand board ft per ac Scribner. The species with the most standing volume on timberland are Douglas-fir, white fir, ponderosa pine, and redwoods. By far the most growing stock volume is Douglas-fir, with 43 percent of the state's 334 billion board feet (net Scribner) (fig. 24). Other notable species with standing volumes above 20 billion board feet (net Scribner) are white fir, ponderosa pine, and redwood. These were also the four species with greatest amount harvested (table 6). Private lands contain 44 percent of timberland volume; however, they were the source of 83 percent of the volume harvested in 2012 (McIver et al. 2015).

Table 5—Aboveground carbon mass[a] of live trees[b] on forest land, by ownership and land status, California 2006–2015

	Land status													
	Unreserved forests						Reserved forests							
	Timberland		Other forest		Total		Productive		Other forest		Total		All forest land	
Ownership	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
	Thousand megagrams													
U.S. Forest Service:														
National forest	365,717.0	7,682.1	25,854.6	2,003.6	391,571.6	7,493.2	124,727.1	5,921.0	16,627.9	1,752.1	141,355.0	5,869.4	532,926.6	8,561.9
Other federal government:														
Bureau of Land Management	10,756.7	2,071.8	6,171.1	857.0	16,927.8	2,222.2	2,517.6	987.0	1,236.4	301.0	3,753.9	1,031.9	20,681.7	2,426.2
Departments of Defense or Energy	249.8	194.7	767.5	274.5	1,017.3	336.5	—	—	141.9	146.8	141.9	146.8	1,159.2	367.1
National Park Service	—	—	—	—	—	—	57,670.0	5,509.3	6,035.2	1,104.8	63,705.3	5,563.8	63,705.3	5,563.8
U.S. Fish and Wildlife Service	—	—	—	—	—	—	26.0	26.6	13.7	13.8	39.7	30.0	39.7	30.0
Other federal	—	—	483.4	154.2	483.4	154.2	—	—	77.4	53.1	77.4	53.1	560.8	163.1
Total	11,006.5	2,077.8	7,421.9	907.8	18,428.5	2,246.0	60,213.6	5,550.4	7,504.6	1,140.8	67,718.3	5,598.6	86,146.7	5,686.2
State and local government:														
Local	2,490.8	1,081.9	2,015.4	522.8	4,506.1	1,209.3	3,384.5	1,353.4	3,308.4	732.5	6,692.9	1,498.0	11,199.1	1,918.8
State	7,459.3	1,976.1	591.5	387.9	8,050.8	1,981.6	28,361.8	6,219.6	4,539.7	1,129.7	32,901.4	6,286.2	40,952.2	5,913.7
Other public	—	—	21.1	19.1	21.1	19.1	310.7	346.0	36.5	39.4	347.1	348.2	368.2	348.7
Total	9,950.1	2,241.9	2,627.9	651.2	12,578.0	2,310.8	32,056.9	6,351.7	7,884.6	1,322.9	39,941.5	6,429.2	52,519.5	6,142.4
Corporate private	144,937.3	5,688.8	11,983.6	1,347.4	156,920.9	5,794.6	—	—	—	—	—	—	156,920.9	5,794.6
Noncorporate private:														
Nongovernmental conservation or natural resource organizations	6,939.6	1,264.8	995.0	250.8	7,934.6	1,289.5	—	—	—	—	—	—	7,934.6	1,289.5
Unincorporated partnerships, associations, clubs	6,624.8	1,647.6	1,157.2	379.5	7,782.0	1,694.2	—	—	—	—	—	—	7,782.0	1,694.2
American Indian	10,350.1	2,297.9	528.0	254.6	10,878.2	2,310.3	—	—	—	—	—	—	10,878.2	2,310.3
Individual	106,188.9	5,962.6	53,911.8	2,475.0	160,100.7	6,232.4	—	—	—	—	—	—	160,100.7	6,232.4
Total	130,103.5	6,432.1	56,592.1	2,504.4	186,695.5	6,650.7	—	—	—	—	—	—	186,695.5	6,650.7
All private	275,040.8	6,924.4	68,575.6	2,757.8	343,616.4	6,904.4	—	—	—	—	—	—	343,616.4	6,904.4
All owners	661,714.4	10,531.7	104,480.1	3,573.7	766,194.5	10,373.8	216,997.7	10,294.2	32,017.0	2,470.9	249,014.8	10,334.2	1,015,209.3	13,134.3

Note: Totals may be off because of rounding; data are subject to sampling error; SE = standard error; — = less than 50 Mg was estimated.

[a] Total aboveground carbon mass of the tree from ground to tip, includes stem wood, bark, and branches; calculated by applying a factor of 0.5 to aboveground biomass estimated from regional biomass equations, and converting to metric units. Convert megagrams of carbon to tons of biomass by multiplying by 2.204586. The result will be approximate because of rounding.

[b] Includes all live trees ≥ 1 inch in diameter at breast height, consisting of growing stock, rough-cull, and rotten-cull tree classes.

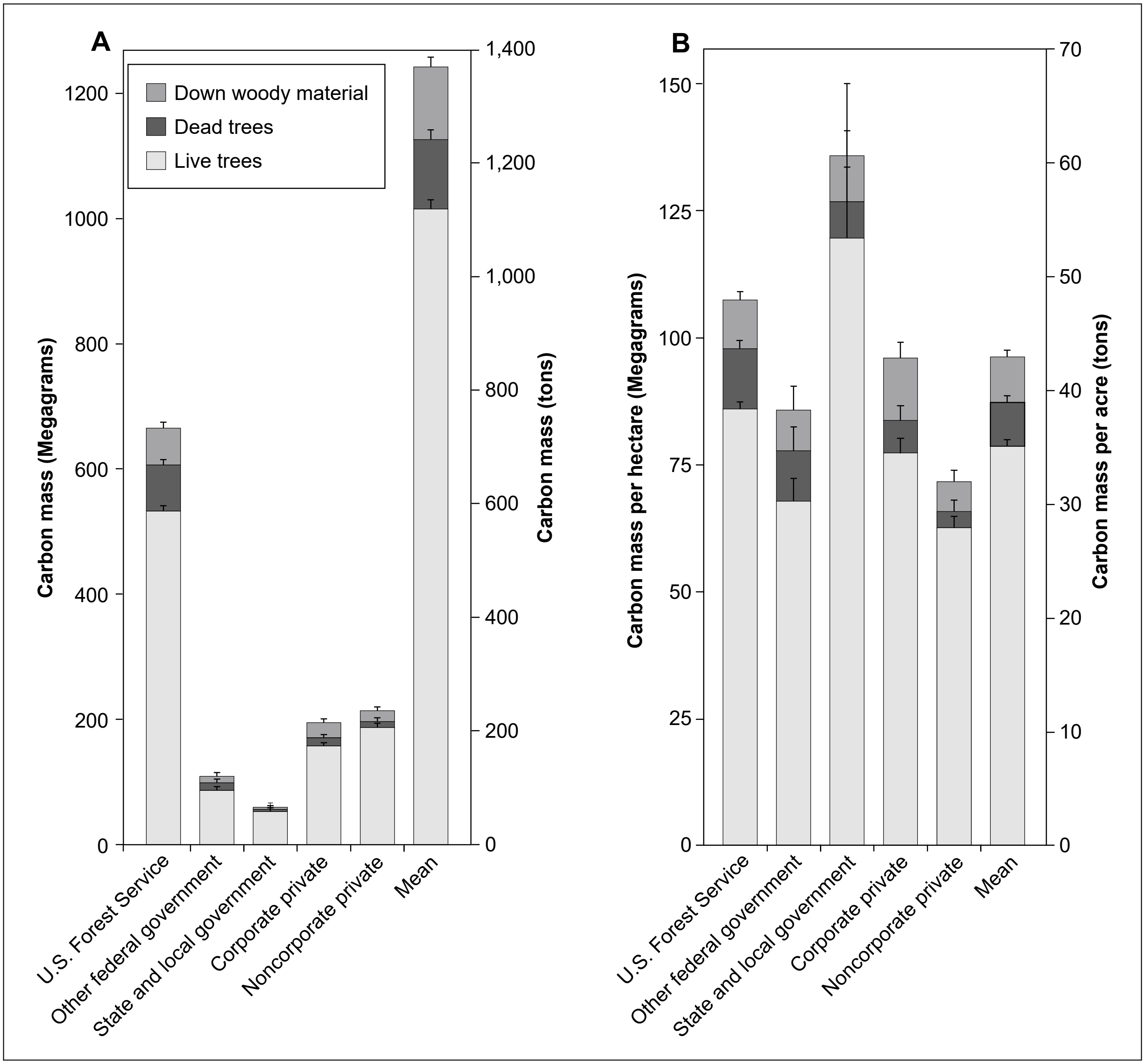


Figure 21—(A) Total aboveground carbon mass and (B) mean density of carbon in aboveground wood on forest land by ownership group, California, 2006–2015.

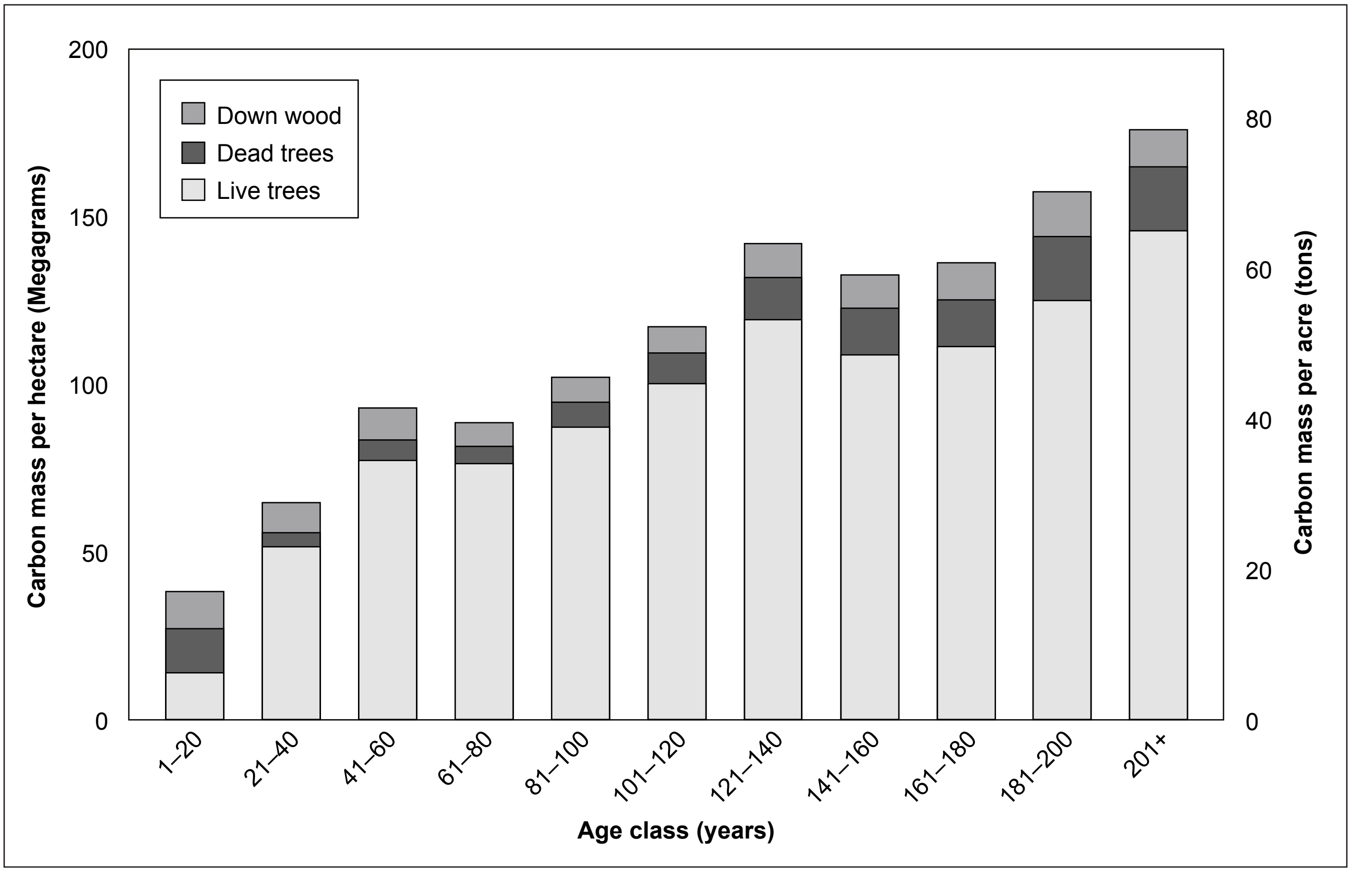


Figure 22—Mean density of elemental carbon in aboveground wood by stand age class on forest land, California, 2006–2015.

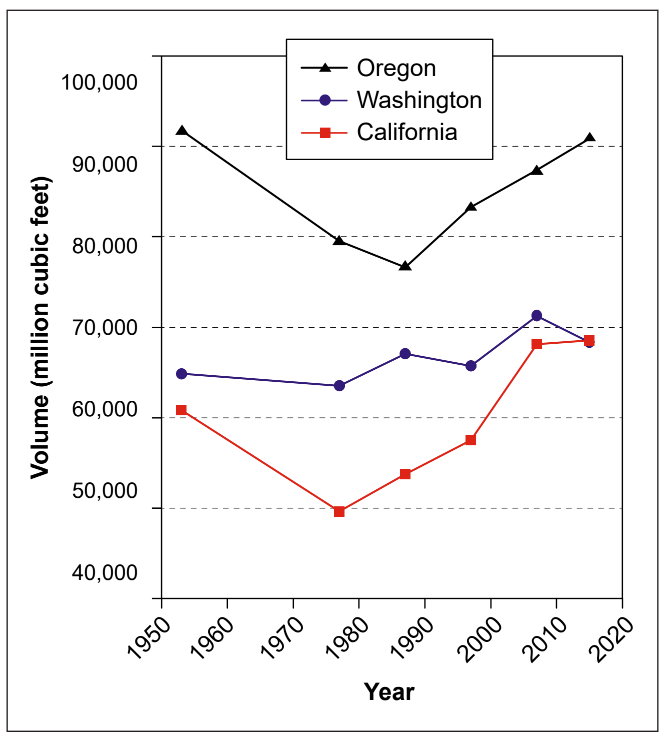


Figure 23—Net volume of growing stock on timberland. Values for years prior to 2015 are from Oswalt et al. (2014). Data represented here are estimates using varying protocols and methodologies.

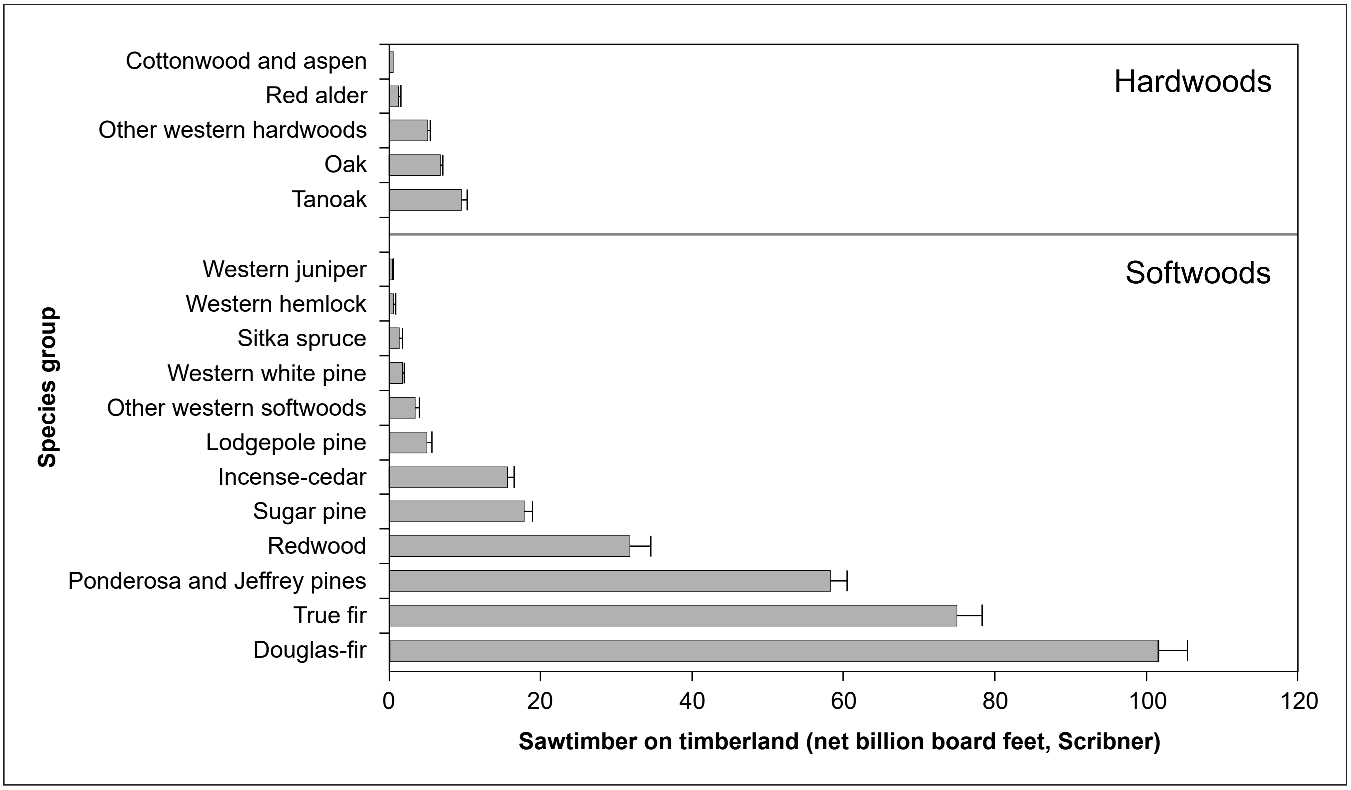


Figure 24—Sawtimber on timberland by species group, California, 2006–2010. Douglas-fir, true fir, ponderosa and Jeffrey pine forest types contain the most volume within the state.

Table 6—California's timber harvest by species, 2012

Species	Volume[a]	Total
	Million board feet	*Percent*
Douglas-fir	405.2	28.4
True firs	380.2	26.7
Ponderosa pine	251.1	17.6
Redwood	209.0	14.7
Sugar pine	86.4	6.1
Incense-cedar	70.1	4.9
Lodgepole pine	14.7	1
Western hemlock	4	0.3
Other softwoods[b]	3.4	0.2
Hardwoods	1.4	0.1
All species	1,425.4	100

[a] Volume is in Scribner Decimal C log rule, east-side variant.
[b] Other softwoods include Jeffrey pine, spruces, giant sequoia, and other coniferous species. Source: McIver et al. 2015.

Site productivity class is another useful measure of yield because it encompasses a site's potential level of volume production—not just what is currently standing. Site productivity class is generally calculated by using the height and age of one or more representative dominant or codominant trees and comparing it to site-index curves that are specific to region and species. The site index is then used to determine MAI, which in turn is used to separate sites into productivity classes (Hanson et al. 2003). Only 6 percent of California's forests are classified as being highly productive (>165 ft/ac/yr). Hardwoods are dominant in the lowest productivity class (site class VII; <20 ft/ac/yr). This site class accounts for the greatest share of forest area but is excluded from being considered as timberland (fig. 25). Although national forests account for most (54 percent) of California's timberland area, corporate forests have a much larger proportion of their forests in highly productive timberland (fig. 14).

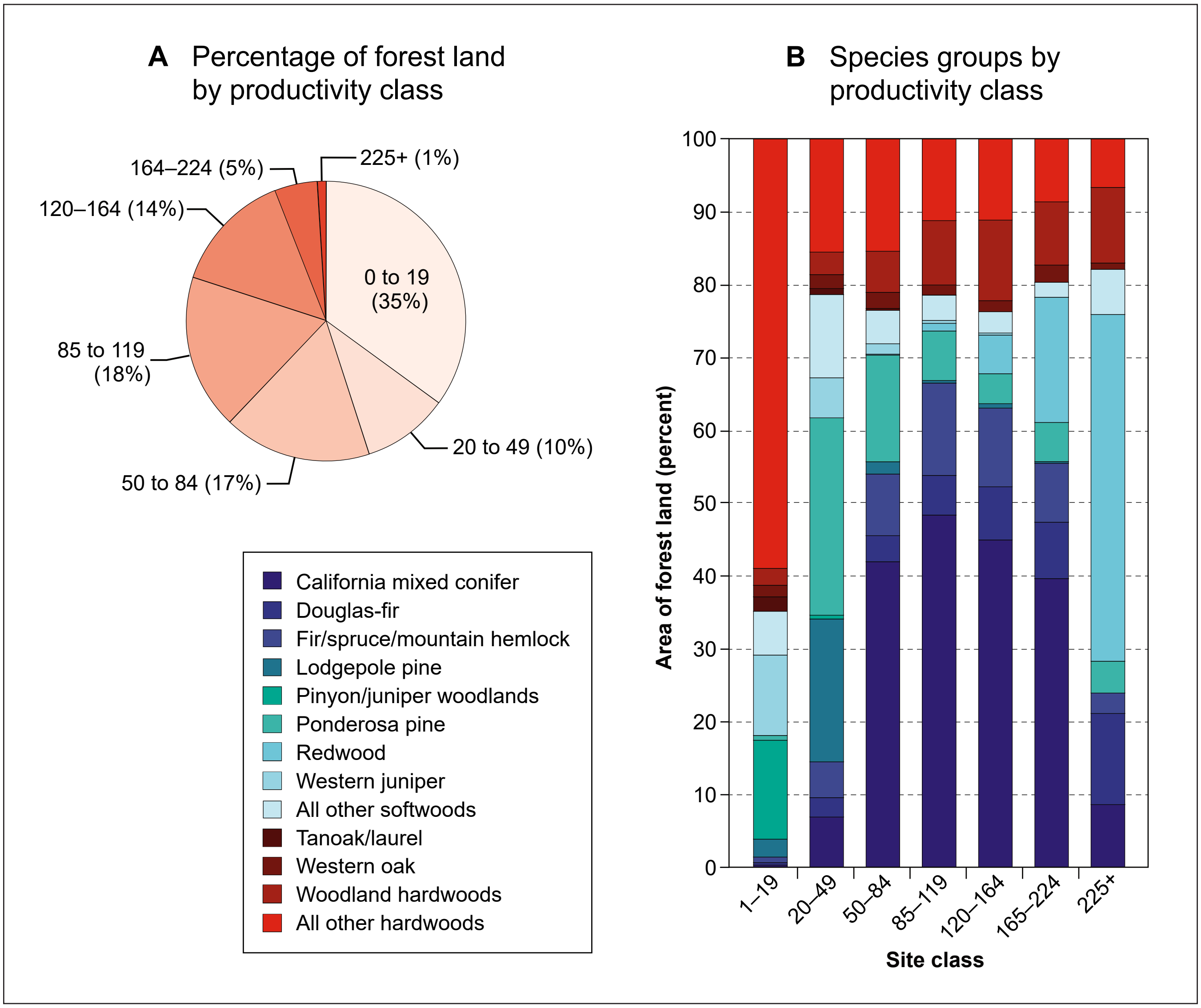


Figure 25—(A) Percentage of forest land in each productivity class and (b) species groups by productivity class. Coniferous forest types dominate in the more productive classes.

Average Annual Growth, Removals, and Mortality

Within the Pacific Northwest region, 10 percent of FIA plots are measured annually such that a full cycle of plots is measured every 10 years. Estimates of mean annual growth, mortality, and removals (harvest, precommercial thinning, or land conversion) can be directly calculated only from plots that have been assessed at least twice. Although the majority of the data presented in this report are from those plots measured in the 10-year period 2006–2015, the figures in this section represent data collected on plots measured in the years 2001–2005 and then again in 2011–2015.

Mean annual gross growth in California was 1.99 million ft/year (table 7). Despite removals (21 percent of growth) and relatively high mortality (45 percent of growth) for all ownership groups, net change was positive (fig. 26A.). On a per-acre basis, corporate forests had the greatest growth and the greatest removals (fig. 26B. and table 8), likely owing to greater control of stocking levels—stand densities are managed to maximize growth rates, and rotation ages are generally lower for this ownership type relative to others (Tappenier et al. 2015). Nearly half (49 percent) of corporate timberlands were under the age of 60. By contrast,

Table 7—Average annual volume (cubic feet) growth, removals, and mortality on forest land by ownership group, California 2001–2005 and 2011–2015

	Ownership group													
							Private							
	U.S. Forest Service		Other federal		State and local government		Corporate		Noncorporate		Total private		All owners	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
	Thousand cubic feet per year													
Growth	914,005	23,949	127,761	15,450	89,521	11,595	504,474	26,049	354,304	22,154	858,779	27,221	1,990,065	39,237
Mortality	639,194	39,324	62,816	11,586	29,836	10,557	90,400	9,741	80,643	7,603	171,042	11,969	902,889	43,770
Removals	51,792	8,994	1,449	1,216	386	206	310,191	38,931	50,664	11,690	360,855	40,081	414,482	41,095
Net change	223,019	45,417	63,496	15,852	59,298	16,448	103,884	44,190	222,998	22,111	326,882	48,812	672,694	70,272

SE = standard error.

Table 8—Average annual volume (cubic feet per acre) growth, removals, and mortality on forest land by ownership group, California 2001–2005 and 2011–2015

	Ownership group													
							Private							
	U.S. Forest Service		Other federal		State and local government		Corporate		Noncorporate		Total private		All owners	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
	Thousand cubic feet per year													
Growth	60.6	1.6	44.5	5.0	86.9	10.1	89.2	3.8	53.3	2.8	69.8	2.2	63.6	1.3
Mortality	42.4	2.6	21.9	3.9	29.0	10.2	16.0	1.6	12.1	1.1	13.9	1.0	28.9	1.4
Removals	3.4	0.6	0.5	0.4	0.4	0.2	54.8	6.7	7.6	1.8	29.3	3.3	13.3	1.3
Net change	14.8	3.0	22.1	5.4	57.6	15.5	18.4	7.8	33.6	3.1	26.6	4.0	21.5	2.2

SE = standard error.

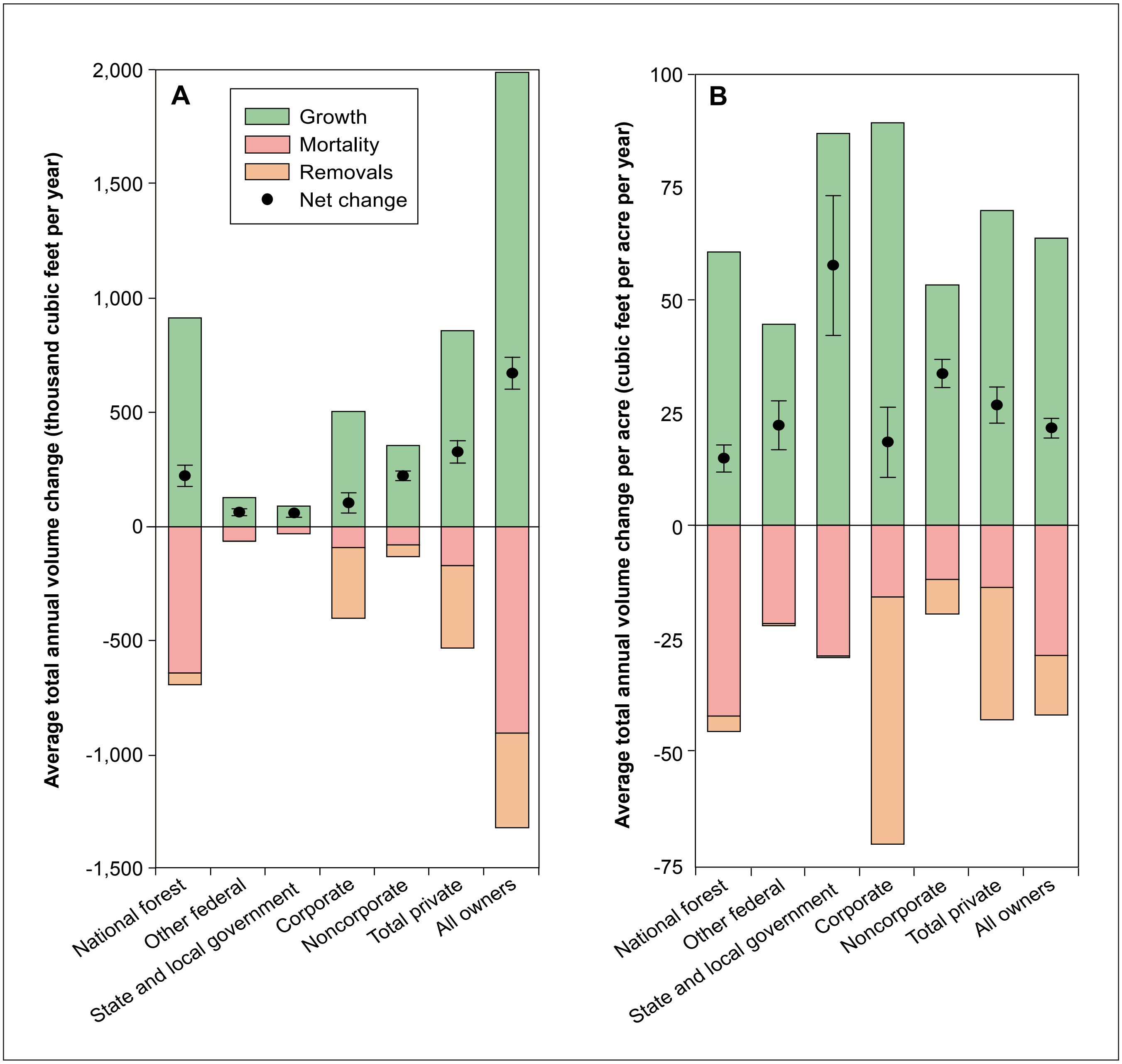


Figure 26—(A) Average total annual volume change by owner, and (B) average annual volume change per acre in California for the 10-year period between 2001–2005 and 2011–2015.

only 17 percent of timberland on national forests were in that age group. The relatively greater productivity of corporate forests (fig. 14) is also likely to contribute to their greater gross growth (table 7). Mortality per acre was dramatically greater on national forests than any other ownership group.

Estimating the net change from the first measurement to the second, the Sitka spruce species group exhibited the greatest net annual growth at 5.6 percent. Owing to the small number of plots in this group, however, these estimations have large associated standard errors (fig. 27). Most of the commercially important species—Douglas-fir, true firs, ponderosa pine, and redwood—had an annual growth rate of approximately 2.0 to 2.5 percent.

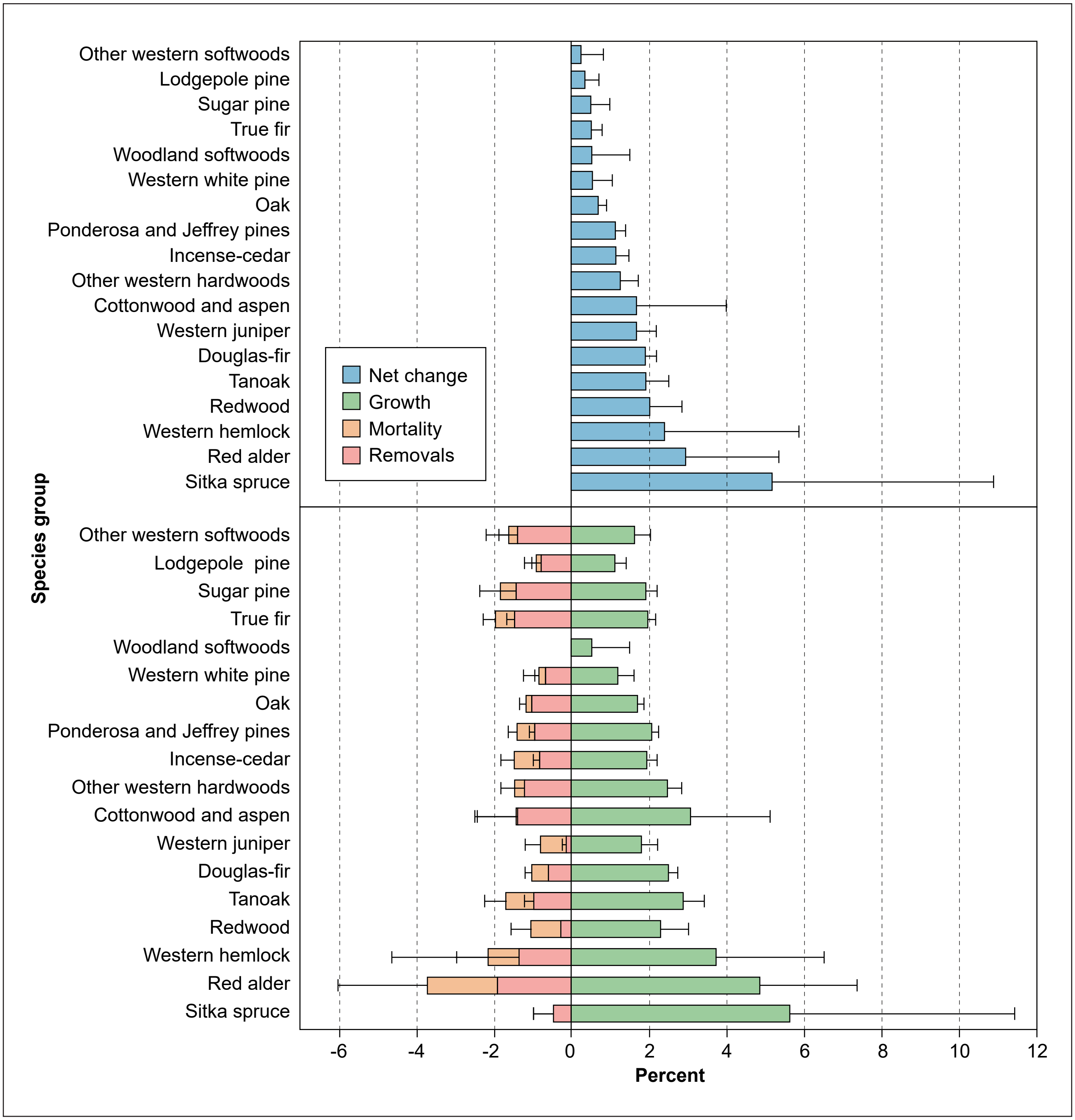


Figure 27—Average total annual volume change by species group in California, 2006–2015.

Standing Dead Trees and Down Woody Material as Part of Wildlife Habitat

Standing dead trees (snags) and down woody material are used by many species of mammals, amphibians, and reptiles (Bull 2002) and are one of several measures of habitat useful to wildlife biologists. FIA data have been used to help qualify and quantify habitat for several wildlife species in California, including fishers (Zielinski et al. 2012), California spotted owls (Bond 2004), pacific giant salamanders, California quail, pileated woodpeckers, mountain lions, and blacktailed deer (Ohmann 1992). Each species requires different habitat characteristics, several of which are measured on FIA plots, including understory species present, overstory composition, overstory structure, and characteristics of the standing dead trees and down woody material (fig. 29). Although standing and down woody material can provide critical habitat for wildlife, heavy accumulation of dead woody material can indicate dense stands undergoing a stem-exclusion stage, problems associated with pathogens, or increased risk of high-intensity fires.

Snag longevity is extremely variable and is dependent on species, diameter, local site conditions, and cause of death. For this reason, the proportion of snags to live trees is not equivalent to mortality rate; however, it does give some indication of snag density within a stand. The

Research Application: Evaluating Opportunities to Increase Climate Benefits by Restoring California's Forests

Jeremy S. Fried and William C. Stewart

Forests can provide climate benefits both from healthy growing forests and from harvested products that continue to store carbon and can also replace fossil fuels. However, the long-term sustainability of various forest preservation and forest utilization strategies is not easy to predict in regions that face an increasing likelihood of severe wildfire. We determined that, despite complex fire and harvest interactions, forest thinning is effective in reducing forest carbon loss resulting from fire and can be cost effective on more than 80 percent of California's timberlands.

The California Energy Commission commissioned a study to determine whether forest thinnings could meet two objectives: (1) provide sustainable feedstock for second generation (cellulosic rather than sugar-based) biofuels, and (2) reduce the risks of forest loss to severe wildfires. We applied the BioSum modeling framework (Fried et al. 2017), which relies on the Forest Inventory and Analysis (FIA) plots as a representative sample of all California forest land, and on the Forest Vegetation Simulator to project plots in commercial forest types in California (mixed conifer, pine, true fir, and Douglas-fir forests). BioSum was used to predict yields and inventories under different fire regimes over four decades using a variety of restoration treatments designed to increase a stand's resistance to fire and other mortality agents. BioSum's integrated economic models also assessed the costs and revenues of different treatments, including tracking the delivery of wood from forest sites to wood processing and bioenergy facilities. Given that the longest lasting climate benefits are likely to accrue in live trees and harvested wood products, we focused on fire-induced tree mortality as a measure of treatment effectiveness. We picked the most effective prescription as the one that led to the lowest mortality rate, calculating mortality volume as a percentage of live tree volume.

Restoration prescriptions could reduce 40-year mean percentage of volume of mortality compared to a grow-only (no-treatment) scenario on 9.4 out of 10.5 million timberland acres. Sales of wood would collect more than enough revenue to cover treatment and transportation costs on 8.6 million of these acres. Restoration was feasible on both private and national forests. Under a scenario with up to $200 per acre of subsidy available to support restoration, treatments could be implemented on an average of 171,000 private and 242,000 national forest acres per year, annually generating 2.9 and 8.4 million

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bone-dry tons per year, respectively, of merchantable wood and 2.3 and 6.7 million bone-dry tons of energy wood. The thinning prescriptions reduced stand density, as assessed by basal area, by 33 percent every two decades, but differed from one another with respect to which trees were thinned, when thinning occurred, and treatment of surface fuels that was used.

In comparing two post-thinning surface fuel treatments (prescribed fire vs. lop and scattering of tops and limbs), an even-age prescription, and the grow-only scenario (fig. 28), prescribed fire appears to be far more effective than lop and scatter in reducing fire risks, and the largest gains in mortality reduction are expected to come from stands with above-average inventories.

To evaluate the effect of thinning treatments on greenhouse gas emissions generated by fires, fire return intervals were also considered. Where mean severe fire return interval was short (40 years), the grow-only scenario generated much greater mortality and emissions compared to restoration treatments. The treatments reduced mortality and moved some of the woody biomass at high risk of producing emissions into wood products. As fire return interval lengthened to greater than 240 years, the reductions in net greenhouse gas emissions from implementing restoration treatments diminished. With fire becoming more frequent across virtually all lands, implementing forest restoration treatments is a "no regrets" strategy that can also provide substantial positive climate benefits in California.

The BioSum framework used for this analysis is now available for anyone to use for analysis in five Western states: California, Idaho, Montana, Oregon, and Washington. It facilitates prospective analysis of all kinds of scenarios involving alternative forest futures using the FIA plot data as a test bed. Software, documentation, articles describing its use, and sample data are available at http://www.biosum.info.

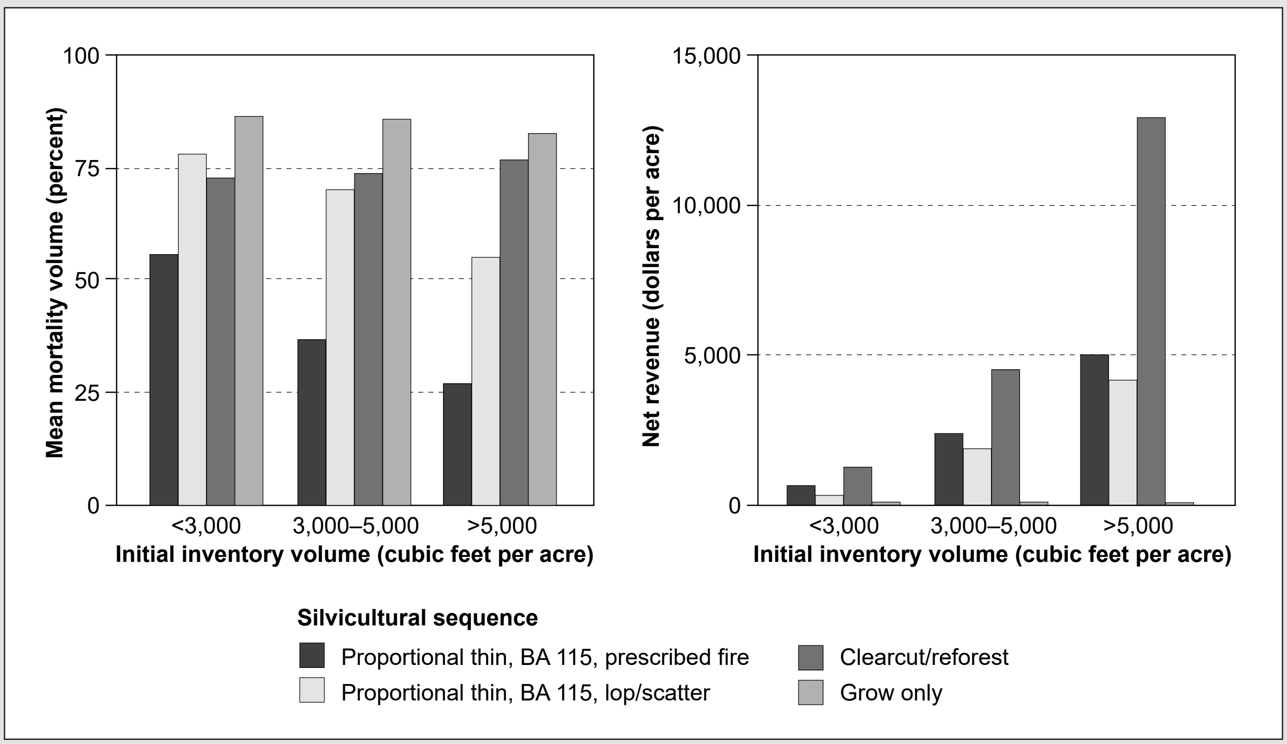


Figure 28—Mean percentage of mortality volume, and net revenue per acre, by stand volume class and silvicultural sequence for two thinning, one clearcut/reforest, and the grow-only sequences. BA = basal area.

Gerad Dean

Figure 29—Snag and down dead tree on a Forest Inventory and Analysis plot in Tulare County, California.

species groups with the highest proportion of dead trees are fir/spruce/mountain hemlock (9.5 percent), woodland hardwoods (8.8 percent), western white pine (8.2 percent) and elm/ash/cottonwood (8.3 percent). Ponderosa pine is of particular importance to cavity-nesting birds because of its relatively high proportion of sapwood, which often decays to form nest sites (Farris 2005). In California, 5 percent of standing ponderosa pines are dead, and these snags are evenly distributed across diameter classes larger than 5 inches. This represents an average of six snags per acre in the ponderosa pine forest type.

Although the amount of down wood is similar across ownership groups, the amount of aboveground biomass in standing dead trees is much lower on private land than on land managed by the Forest Service (fig. 30). This is likely to be associated with the greater management intensity on the majority of privately owned lands; stocking levels are controlled to reduce density-induced mortality driven by competition for resources. Moreover, management entries on private lands are generally more frequent, providing opportunities for sanitation and salvage, thereby reducing the population of dead and dying trees that could represent a hazard during logging operations. The Occupational Safety and Health Administration stipulates that a dead tree “must be felled or avoided by at least two tree lengths” (USDL OSHA 2017). Biomass density of down wood is greatest in the redwood, alder/maple, Douglas-fir, and tanoak/laurel forest types (averaging 21.3, 14.3, 13.9, and 12.1 tons/ac, respectively, across the state).

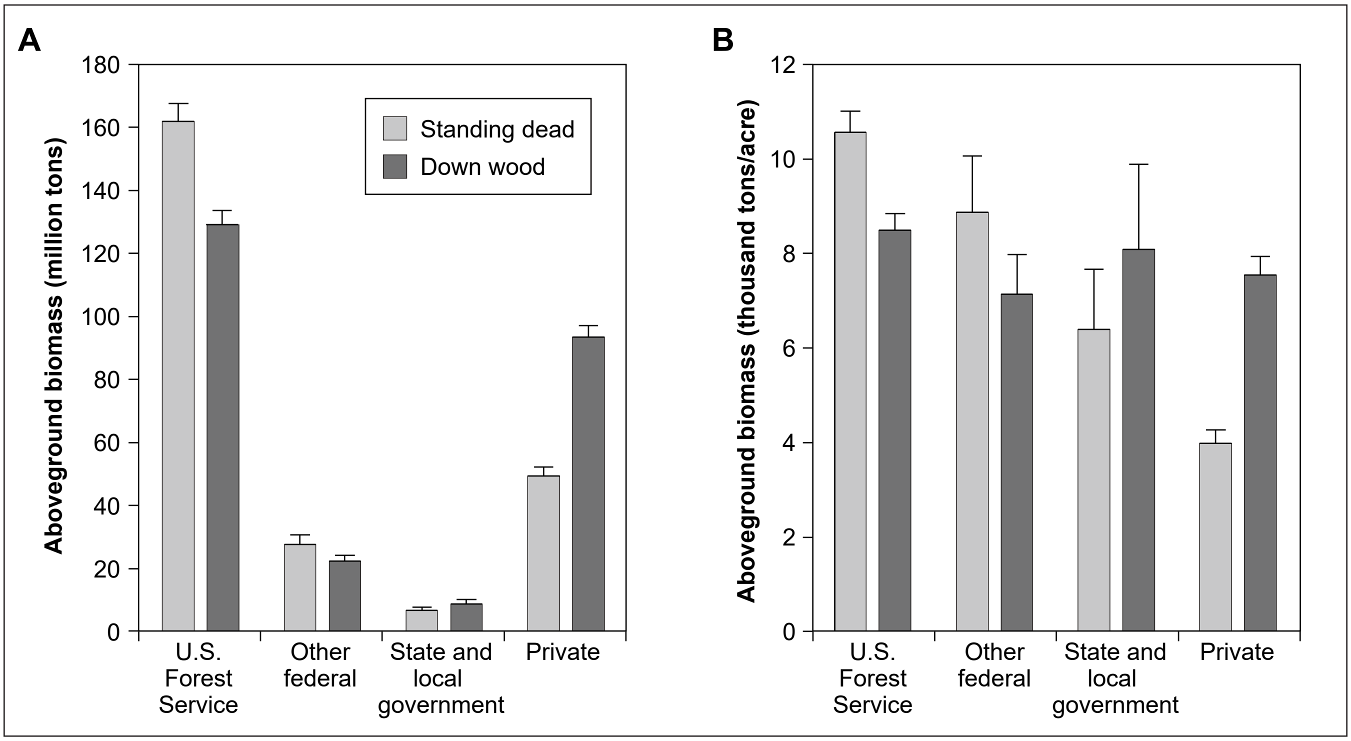


Figure 30—(A) Total aboveground biomass and (B) aboveground biomass per acre by ownership type in California, 2006–2015.

Understory Vegetation and Nontimber Forest Products

Understory species are recorded on FIA plots if at least 3 percent cover is present. Although this minimum cutoff level may not be appropriate for assessments of species richness or presence of species with dispersed growth habits, it is extremely useful for assessing large-scale trends and stand-level attributes. For example, characterization of understory composition and structure can be used as indicators of wildlife habitat, successional stage, or for modeling species range maps.

Young forests in California have a shrub-dominated understory (figs. 31 and 32). Older dry hardwood forests, however, also had a high percentage of cover of graminoid species. Cover of all forest understory components—forbs, shrubs, and grasses—tends to decrease as stand age increases to more than 160 years. The only category that increased as stand age increased was graminoids in the wet hardwood forest type class, which showed a slight increase in cover from 4 to 12 percent. The high standard error associated with this class is the result of the low number of plots in this comparatively uncommon forest type group.

Of the two most common forest types—California mixed conifer and western oak——the dominant understory species differ as stand age increases (table 9). In the California mixed-conifer forest type, native shrubs are prevalent within all age classes. In the western oak type, nonnative grass species are common, especially in the 161- to 200-year age class.

Nonnative species can affect ecosystem composition and function and in some cases can have a significant economic impact (Gray et al. 2011). The two nonnative species with the most land cover in California are both grasses—cheatgrass (*Bromus tectorum)* and ripgut brome (*Bromus diandrus)*—and occur commonly in the western oak forest type (fig. 33). They cover 277,000 and 234,000 ac, respectively.

Nontimber forest products (NTFPs) are important both culturally and economically. For example, in northern California, traditional baskets made by the Klamath Tribes are produced from many plants, including fibers from pine, hazel, beargrass, maidenhair, and giant chain ferns (fig. 34). Collection of mushrooms and other fungi is of growing

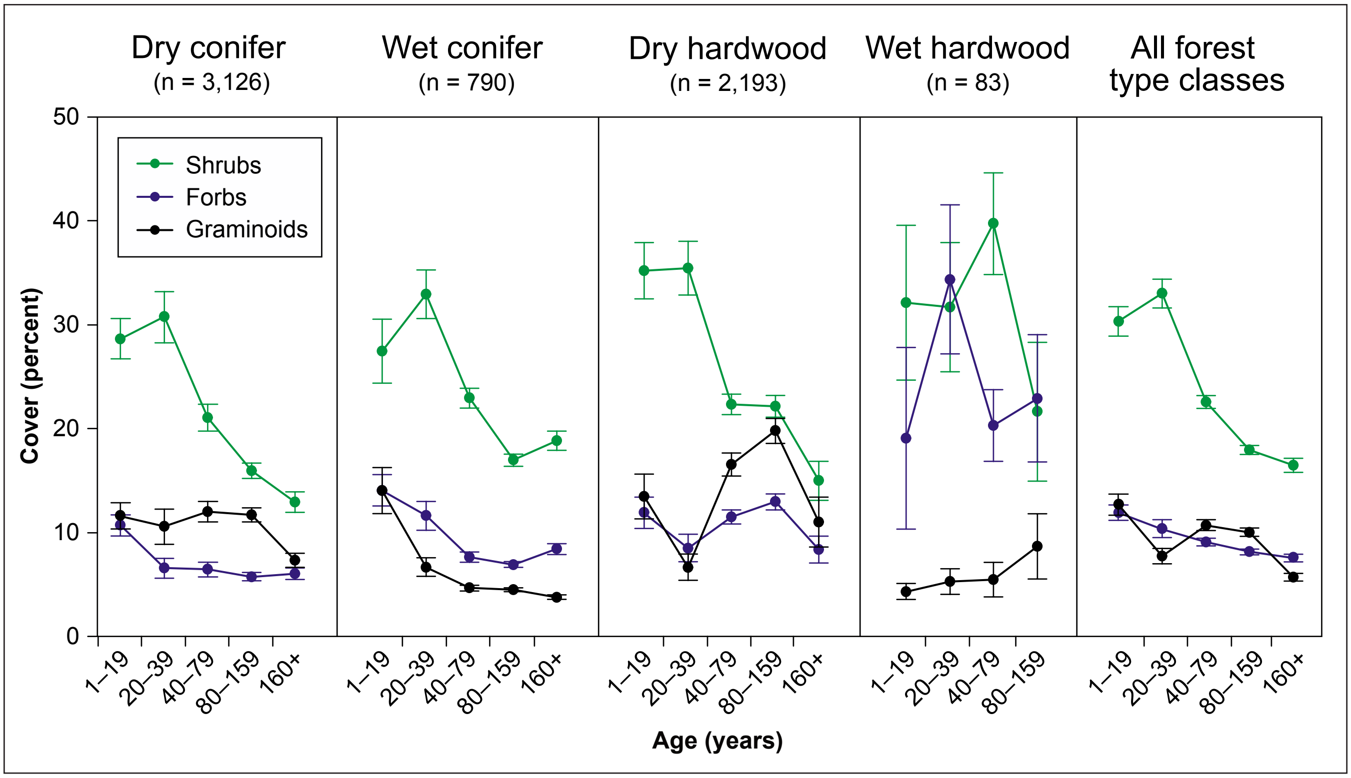


Figure 31—Average percentage of cover by understory life form and forest type group, California, 2006–2015. Does not include plots (predominantly hardwood) where age could not be ascertained.

U.S. Forest Service

U.S. Forest Service

Figure 32—Forests with an understory dominated by shrub species are common in California.

Table 9—Understory species with the greatest percentage cover by stand age class and forest type group for the most common softwood and hardwood forest type groups, California 2006–2015

	California mixed conifer			Western oak		
Age group	Type	Scientific name	Common name	Type	Scientific name	Common name
Years						
1–40	Shrub	*Ceanothus integerrimus*	Deerbrush	Shrub	*Toxicodendron diversilobum*	Pacific poison oak
	Shrub	*Ceanothus cordulatus*	Whitethorn ceanothus	Shrub	*Ceanothus cuneatus*	Buckbrush
	Shrub	*Arctostaphylos patula*	Greenleaf manzanita	Shrub	*Ceanothus integerrimus*	Feerbrush
	Shrub	*Chrysolepis sempervirens*	Bush chinquapin	Shrub	*Chamaebatia foliolosa*	Mountain misery
	Shrub	*Ceanothus velutinus*	Snowbrush ceanothus	Shrub	*Arctostaphylos patula*	Greenleaf manzanita
41–80	Shrub	*Quercus vacciniifolia*	Huckleberry oak	Shrub	*Toxicodendron diversilobum*	Pacific poison oak
	Shrub	*Arctostaphylos patula*	Greenleaf manzanita	Graminoid	*Avena fatua*[a]	Wild oat
	Shrub	*Ceanothus integerrimus*	Deerbrush	Shrub	*Chamaebatia foliolosa*	Mountain misery
	Shrub	*Chamaebatia foliolosa*	Mountain misery	Shrub	*Ceanothus cuneatus*	Buckbrush
	Shrub	*Chrysolepis sempervirens*	Bush chinquapin	Graminoid	*Cynosurus echinatus*[a]	Bristly dogstail grass
81–120	Shrub	*Arctostaphylos patula*	Greenleaf manzanita	Shrub	*Toxicodendron diversilobum*	Pacific poison oak
	Shrub	*Ceanothus integerrimus*	Deerbrush	Graminoid	*Avena fatua*[a]	Wild oat
	Shrub	*Chamaebatia foliolosa*	Mountain misery	Shrub	*Chamaebatia foliolosa*	Mountain misery
	Shrub	*Chrysolepis sempervirens*	Bush chinquapin	Shrub	*Ceanothus cuneatus*	Buckbrush
	Shrub	*Ceanothus prostratus*	Prostrate ceanothus	Graminoid	*Cynosurus echinatus*[a]	Bristly dogstail grass

Table 9—Understory species with the greatest percentage cover by stand age class and forest type group for the most common softwood and hardwood forest type groups, California 2006–2015 (continued)

	California mixed conifer			Western oak		
Age group	Type	Scientific name	Common name	Type	Scientific name	Common name
Years						
121–160	Shrub	*Arctostaphylos patula*	Greenleaf manzanita	Shrub	*Toxicodendron diversilobum*	Pacific poison oak
	Shrub	*Chamaebatia foliolosa*	Mountain misery	Shrub	*Arctostaphylos patula*	Greenleaf manzanita
	Shrub	*Ceanothus cordulatus*	Whitethorn ceanothus	Shrub	*Chamaebatia foliolosa*	Mountain misery
	Shrub	*Ceanothus integerrimus*	Deerbrush	Graminoid	*Brachypodium distachyon*[a]	Purple false brome
	Shrub	*Symphoricarpos mollis*	Creeping snowberry	Forb	*Trifolium*[a]	Clover
161–200	Shrub	*Ceanothus cordulatus*	Whitethorn ceanothus	Graminoid	*Bromus diandrus*[a]	Ripgut brome
	Shrub	*Arctostaphylos patula*	Greenleaf manzanita	Graminoid	*Avena fatu*[a]	Oat
	Shrub	*Ceanothus integerrimus*	Deerbrush	Graminoid	*Bromus* spp. (some[a])	Brome
	Forb	*Pteridium aquilinum*	Western brackenfern	Forb	*Cirsium*[a]	Thistle
	Shrub	*Symphoricarpos mollis*	Creeping snowberry	Forb	*Erodium*[a]	Stork’s bill
201+	Shrub	*Arctostaphylos patula*	Greenleaf manzanita	Shrub	*Toxicodendron diversilobum*	Pacific poison oak
	Shrub	*Arctostaphylos nevadensis*	Pinemat manzanita	Shrub	*Ceanothus integerrimus*	Deerbrush
	Shrub	*Ceanothus integerrimus*	Deerbrush	Graminoid	*Bromus tectorum*[a]	Cheatgrass
	Shrub	*Chrysolepis sempervirens*	Bush chinquapin	Shrub	*Eriogonum fasciculatum*	Eastern Mojave buckwheat
	Shrub	*Chamaebatia foliolosa*	Mountain misery	Shrub	*Holodiscus discolor*	Oceanspray

Note: Does not include plots (mostly hardwood) where age was not ascertained.
Species are listed in order of predominance by age group for plots in which age could be determined.
[a] Nonnative species.

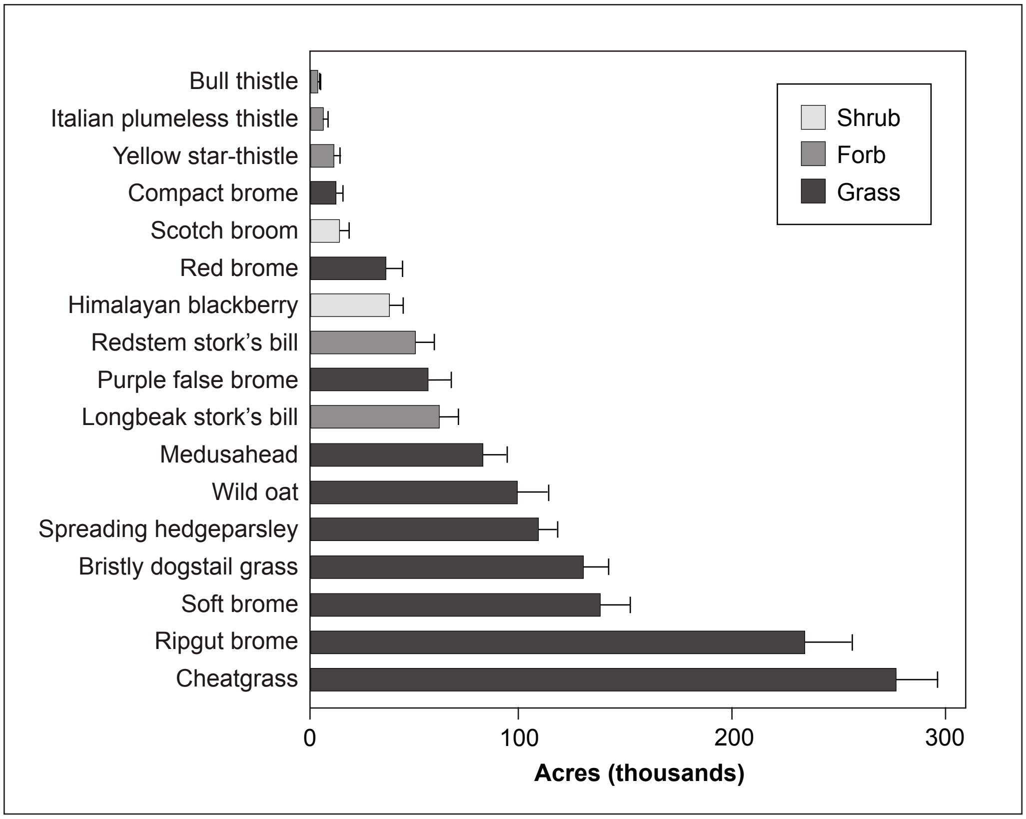


Figure 33—Estimated number of acres covered by the most abundant nonnative species in California, 2006–2015.

Daderot

Figure 34—Traditional basket from the Klamath region made of nontimber forest products on display in the Oakland Museum of California.

commercial importance; in 2007, permits for the harvest of 42,196 lbs of mushroom and fungus harvest were granted by the Forest Service and the Bureau of Land Management in California (Alexander et al. 2011). Other NTFPs include berries, nuts, medicinal plants, materials suitable for transplanting, and floral and Christmas greens. Covering 397,000 ac, the most abundant species is the greenleaf manzanita (fig. 35), which can be used for medicinal purposes or for decorative wood crafts (USDA NRCS 2000).

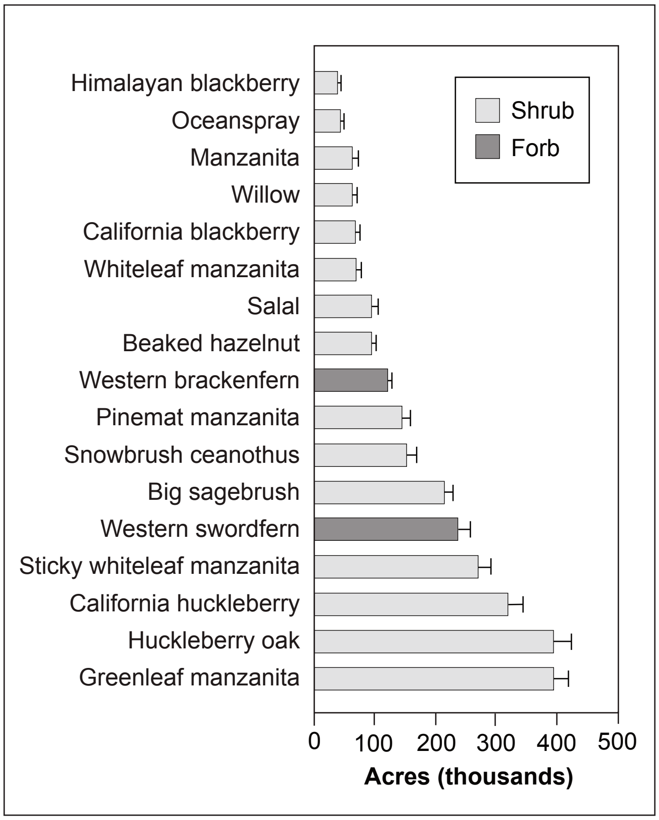


Figure 35—Estimated number of acres covered by the most abundant nontimber forest products in California, 2006–2015.

Forest Health

Tree Damage

Damages were recorded for each live tree on FIA plots. For 2013 and subsequent years, a nationally consistent coding system was used. The new system and the regional one used previously are compatible and are outlined in O'Connell et al. (2017). Although tree damage or defect may not result in a reduction of merchantable volume or be severe enough to slow growth, recording presence of any damage is important to monitor the presence of pathogens or to help quantify large-scale weather and fire events. For example, using FIA data, it has been estimated that about six invasive species (arthropods and others) per year have become established in the forests of California (Vogt and Koch 2016).

By far the most common group of damages in live trees consists of those caused by a physical injury (such as from historical fires or logging), or are unattributed physical defects (such as broken or dead tops, forks, crooks, or cracks). This category of damages was estimated to affect 27,703 million ft of volume—26 percent of total gross standing volume. Stem decay and root disease were the second and third largest category, affecting 6.2 and 5.2 percent of gross volume, respectively. Dwarf mistletoe was also prevalent in conifer species (fig. 36). In addition to FIA data, the Forest Service also collates forest insect and disease data from many state, county, and local sources and publishes summaries on the Forest Health Technology Enterprise Team Mapping and Reporting website (USDA FS 2017a).

For some of the most commercially important species, damage was present in 17 to 27 percent of trees sampled, including Douglas-fir (17 percent), white fir (27 percent), ponderosa pine (20 percent), and redwood (17 percent). California red fir had the greatest percentage of trees with bark beetle damage (1.6 percent), followed by single-leaf pinyon (1.0 percent). Although statewide numbers may appear low for bark beetle incidence, localized values may be extremely high. Within individual stands, species composition, density, age structure, and lack of vigor (resulting from drought or the presence of other pathogens) can increase susceptibility to bark beetle outbreaks (USDA FS 2015).

In addition to damages on live trees, FIA crews also record cause of death when possible. Cause of death is often difficult to ascertain, but of the trees for which it could be identified, 52 percent of deaths were attributed to fire, 24 percent to disease, and 7 percent to insects. The two highest categories by species group were mortality of Engelmann spruce (*Picea engelmanni*) and other spruces resulting from fire (47 percent), and cottonwood and aspen mortality resulting from disease (41 percent).

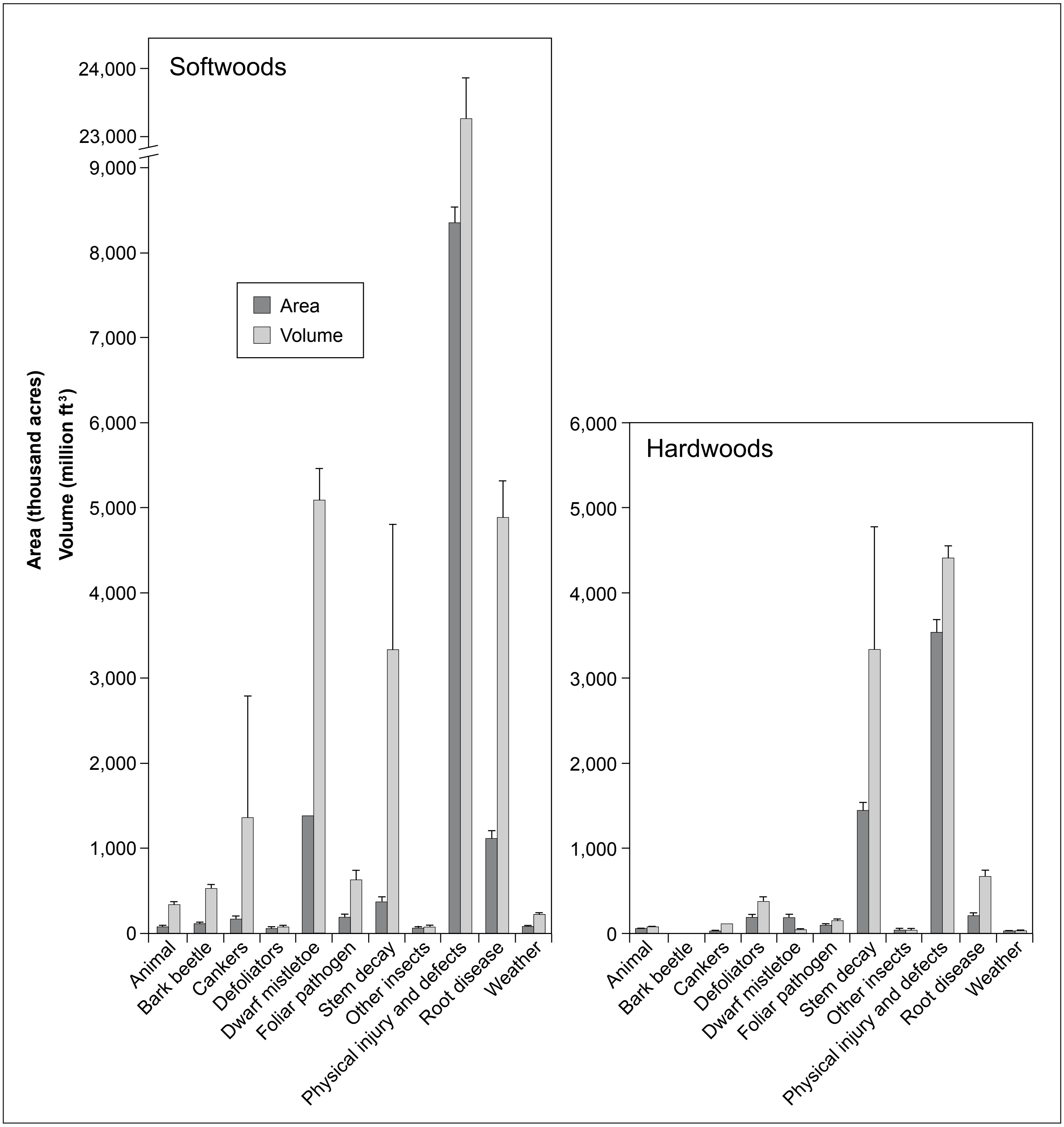


Figure 36—Area of forest land with greater than 25 percent basal area damaged and total volume of trees with damage in California, 2006–2015.

Mortality of ponderosa, Jeffrey, and lodgepole pine forest types, which has been of concern in localized areas because of drought and bark beetles, was 7 percent statewide, but is much higher in concentrated areas (fig. 37). The west side of the Sierra Nevada Range and low- to mid-elevation forests are particularly vulnerable. Aerial surveys estimated that 29 million trees died within the state in 2015, primarily from drought-weakened trees that are increasingly susceptible to wood-boring insects (USDA 2016). The dead trees can pose a danger in developed areas owing to their increased likelihood of falling. As drought conditions continue, these forests are also thought to be increasingly predisposed to high-intensity fires. Local tree mortality surveys are now conducted annually by air to more closely monitor the situation and have estimated that the total drought-related tree mortality occurring in years 2010–2017 is 129 million trees. Ten counties in California have been identified by the Tree Mortality Task Force as "high-priority" focus areas (fig. 38) (Tree Mortality Task Force 2018).

U.S. Forest Service Pacific Southwest Region

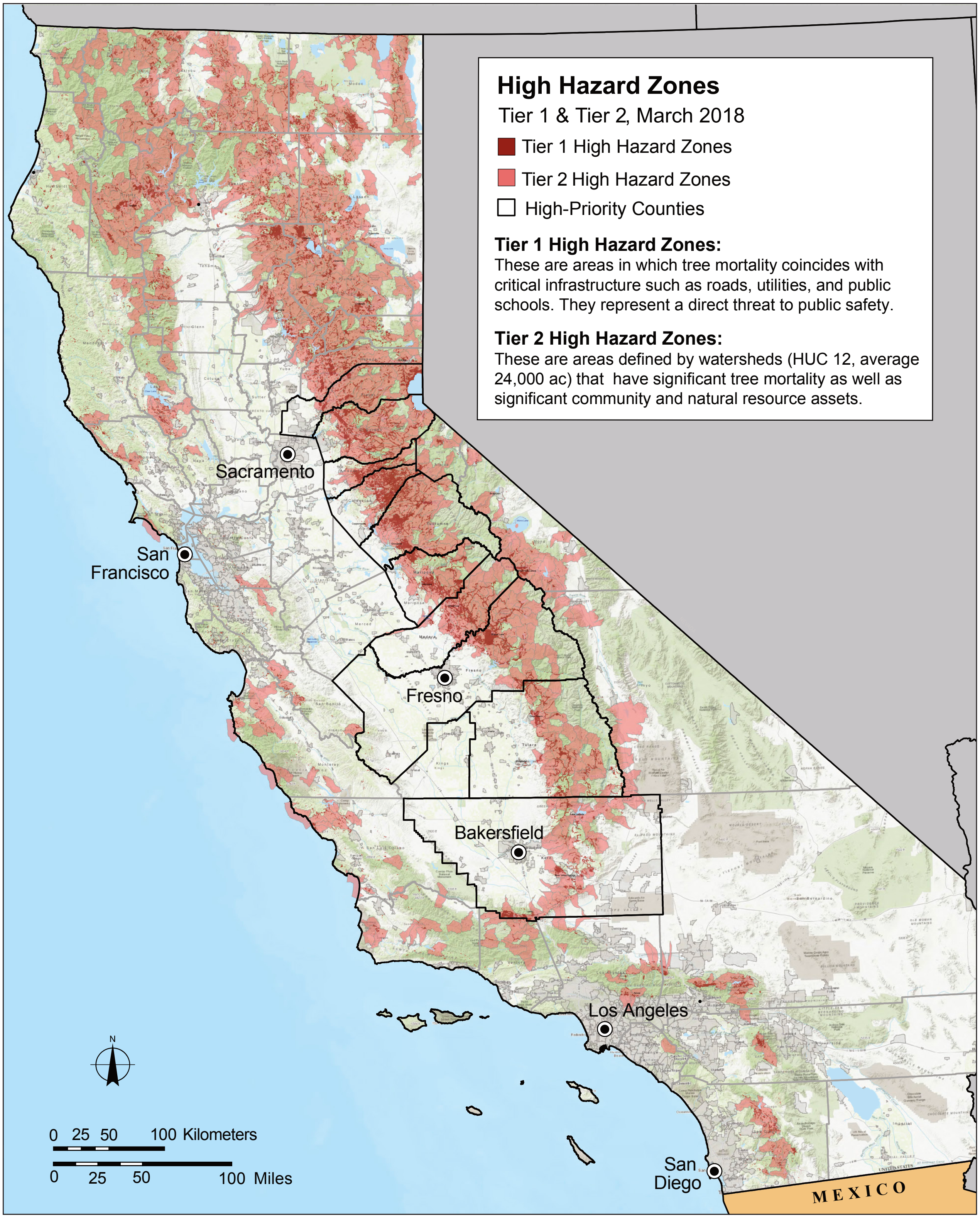
Figure 37—Tree mortality resulting from drought, bark beetle infestation, and high tree densities have reached high levels, particularly in the central and southern Sierra Nevada.

Wildfire

Many tree species native to California are well adapted to periodic low-intensity fires (Sugihara et al. 2006). Although average fire size, intensity, and extent into higher elevations have increased in recent years (Dennison et al. 2014, Miller 2009, Schwartz et al. 2015), mortality resulting from fire can be difficult to assess on a large scale. Complicated interactions exist between species resistance, fire intensity, the uneven distribution of burned areas, and the fact that mortality can be delayed for several years after injury (fig. 39) (Hood et al. 2007). Moreover, mortality is often caused by more than one agent, for example, fire-weakened trees can subsequently be attacked by beetles (Hood et al. 2010).

On new FIA plots, burned areas of at least 1 acre in size and occurring within the past 5 years are recorded. On remeasured plots, evidence of fire disturbance occurring since the last measurement (generally 10 years prior) is recorded. For individual trees, fire can be recorded as a damage for live trees or as a cause of death for dead trees (fig. 40). Additional plot measurements have been undertaken as part of FIA's Fire Effects and Recovery Study to increase our understanding of how postfire conditions relate to prefire conditions and to monitor recovery following a fire event (see sidebar on page 45).

In the period 2006–2015, an estimated average of 399,889 (+ 80,388) ac of forest land burned each year in California. The most acres were burned in years 2008 and 2015. In each of those years, about 50 percent of fires occurred in the northern interior—535,000 and 439,000 ac, respectively. The two most common forest types burned were California mixed conifer (28 percent of fire plots) and canyon live oak (11 percent). Douglas-fir was the species with the greatest incidence of fire damage on live trees with 2.7 million within the state, however, this accounts for only 0.2 percent of live Douglas fir trees. California torreya, Pacific yew, foxtail pine, and Great Basin bristlecone pine were species for which the highest proportion of trees were damaged by fire—all between from 1.6 to 2.1 percent of trees of that species in the state. Additional information and estimates based on alternative methodologies are available through the National Interagency Coordination Center .



Tree Mortality Task Force

Figure 38—Aerial detection survey coverage of drought-related tree mortality and high hazard zones in California, 2018. HUC = hydrologic unit code.

M. Zueger

L. Salmonson

Figure 39—Two plots with evidence of fire in northern California. Fires can differ greatly in intensity and in patchiness.

Research Application: Postfire Woody Carbon and Fuel Dynamics in California's Forests

Vicente J. Monleon

Forest wildfires have an immediate effect in carbon stocks, but they also initiate a series of changes that may last for decades. Wildfires result in transfer from the live to dead carbon pools, and from the dead carbon pools to the atmosphere, a transfer that would eventually be offset by new growth from regeneration. Although total postfire carbon emissions can be much greater than direct combustion emissions, carbon dynamics following wildfires are still a critical gap in the understanding of forest carbon fluxes. Given the importance of wildfire in the Western United States, Forest Inventory and Analysis (FIA) started the Fire Effects and Recovery Study in 2003. One year after a large wildfire, and depending on the availability of funds, all the FIA plots within the fire perimeter were measured, regardless of panel assignment. These plots were measured again at the standard remeasurement cycle, resulting in repeated plot measurements and allowing for estimation of postfire trends.

We examined the postfire dynamics of aboveground woody carbon pools (live trees, snags, and large downed wood) from 130 plots sampled within 32 wildfires, up to 6 years after the fire (Eskelson et al. 2016). During this time, there was no evidence of a net change in the total woody carbon in the stand. However, there were differences in the dynamics of the three pools depending on fire severity (fig. 41). In high-severity fires, where the majority of trees died, there was transfer between snags and downed wood, as standing dead trees fell. In low-severity fires, most of the trees survived the fire. However, some of the surviving trees died in following years and resulted in a transfer of carbon from live to dead pools. Moderate-intensity fires followed an intermediate pattern.

Wildfires also have a direct and a delayed effect on forest fuels. Fires consume fuels, but fuels start accumulating after fires occur. The rate of fuel recovery may determine the likelihood and severity of a reburn. We examined the patterns of postfire forest fuel accumulation in 191 plots from 49 fires in dry conifer

Continued on page 46

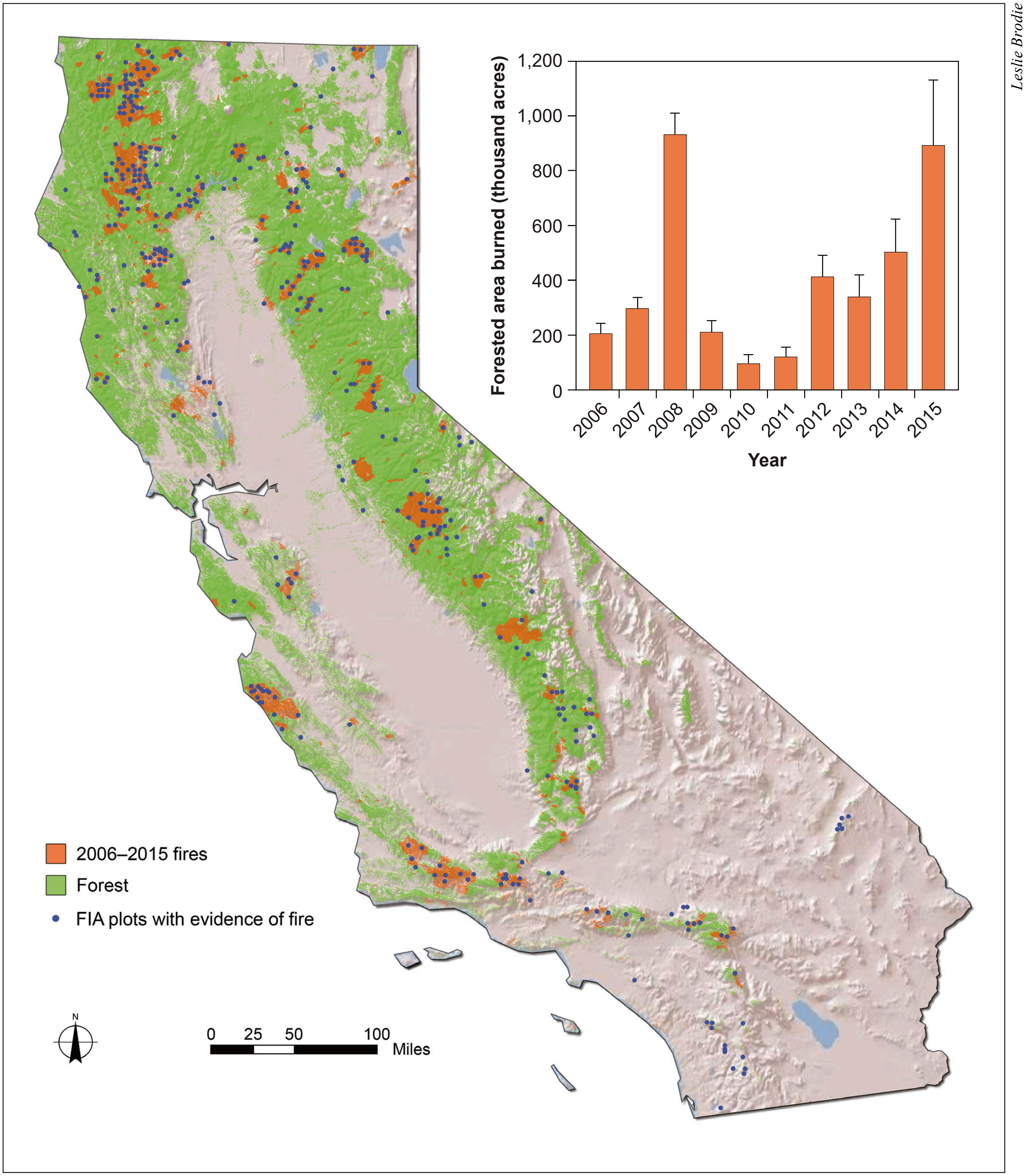


Figure 40—(A) Map of fires that occurred in the period 2006–2015 (CAL FIRE 2016b) on forested land, including the approximate location of Forest Inventory and Analysis (FIA) plots with evidence of fire. (B) Graph shows acreage burned during this period (Homer et al. 2015).

Continued from page 44

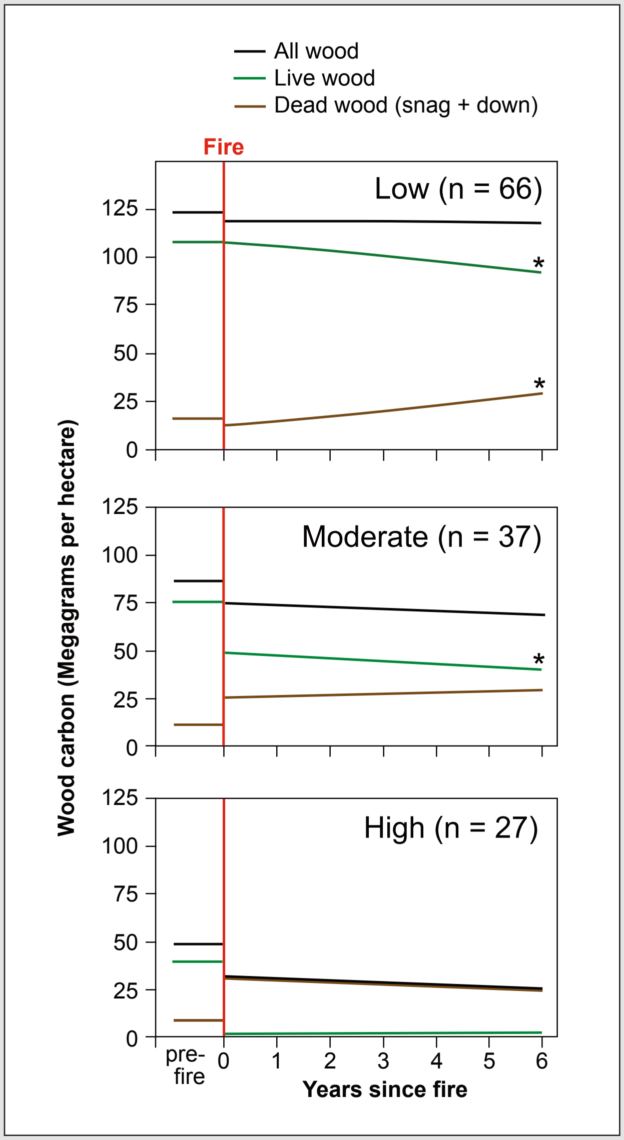


Figure 41—Estimated mean trend of postfire forest carbon pools for low-, moderate-, and high-severity fires. Statistically significant trends are indicated by an asterisk (Eskelson et al. 2016).

and hardwood forests in California, across three fire severity classes, for up to 9 years after the fire (Eskelson and Monleon 2018). During this time, there was no significant change in the duff biomass, regardless of forest type and fire severity. The litter and finest fuel loadings peaked 6 years after the fire for conifer stands, but increased at a constant rate in hardwood stands. The loading of largest fuel classes increased at a constant rate for both forest types, but the rate of increase differed depending on fire severity.

The use of inventory data to obtain empirical estimates of fire effects has a distinct advantage over other approaches. The sample of plots is a random sample distributed across the entire state and therefore covers all the variability in the state. The different conditions are represented in roughly the same proportion as they occur in the landscape. As a result, the estimated trends are representative and can be generalized to all fires in the region. In contrast, most studies are case studies that focus on a narrow set of conditions, restricting the range of variables such as fire severity, stand age, or forest type, which also limits the scope of the conclusions. Particularly interesting was the effect of fire severity. Although most previous case studies have focused on high-severity fires, we found that the majority of stands burned with low and moderate severity (approximately 45 and 30 percent of the plots, respectively). Prefire biomass, biomass combustion, and postfire dynamics differ significantly among fire-severity classes, suggesting that some of the assumptions regarding fire effects may require reevaluation.

Conclusion

Forests are dynamic ecosystems shaped by many factors and will continue to change over time. There are indications from FIA data and other sources that, in the last century, the structure of Californian forests has shifted to fewer large trees, denser stands, and less pine (Dolanc et al. 2014, McIntyre et al. 2015, Stewart et al. 2016). With its Mediterranean climate, droughts have not been uncommon in California's history and are one of the elements influencing local forests. The 4-year period between 2011 and 2015, however, was the driest since recordkeeping began in 1895. Moreover, 2014 and 2015 were the two hottest years up to that time, and more recent years have proven hotter still (USDC NOAA 2017). Drought and heat will likely continue to be significant factors.

Changes in forest extent and structure are not all climate related. Policy, ownership, and management objectives also play a role. Private-sector owners of the forest will respond to various market signals related to commodity prices, amenity values, and real estate values. The set of directives mandated by the passage of the 2012 Planning Rule will significantly change the way that management objectives are set for national forests. The planning rule emphasizes "balancing economic and social values with ecological integrity." Furthermore, it stipulates that collaboration and public involvement become part of the decisionmaking process (USDA FS 2016c). As management objectives continue to evolve in response to changing environmental, climate, and social factors, so too will our forests change.

Tables in Online Supplement

A suite of 125 summary data tables accompanies this report. They are available online at https://www.fs.fed.us/pnw/pubs/pnw_gtr983-supplement.pdf and are listed below for reference.

Number of Plots

Table 1—Number of Forest Inventory and Analysis plots measured by sample status, land class, and ownership group, California, 2006–2015

Area

Table 2—Area of sampled land and water, by land status and ownership group, California, 2006–2015

Table 3—Area of forest land, by county and land status, California, 2006–2015

Table 4—Area of forest land, by county and ownership group, California, 2006–2015

Table 5—Area of forest land, by ownership and land status, California, 2006–2015

Table 6—Area of forest land, by forest type group and land status, California, 2006–2015

Table 7—Area of forest land, by forest type group and site productivity class, California, 2006–2015

Table 8—Area of forest land, by forest type group, ownership group, and land status, California, 2006–2015

Table 9—Area of forest land, by forest type group and stand size class, California, 2006–2015

Table 10—Area of forest land, by forest type group and stand age class, California, 2006–2015

Table 11—Area of forest land by ecological section and land status, California, 2006–2015

Table 12—Area of forest land, by forest type group and stand origin, California, 2006–2015

Table 13—Area of timberland, by forest type group and stand size class, California, 2006–2015

Number of Trees

Tree Volume

Biomass

Carbon

Down Wood

Combined Dead Trees and Dead Wood (Standing Dead Trees and Down Wood)

National Forest

Tree Damage

Understory Vegetation

Timber Products Output and Removals

Annual Growth, Removals, and Mortality

Evidence of Fire

Common and Scientific Plant Names

Life form	Common name	Scientific name
Trees:	Alder	*Alnus* Mill.
	Ash	*Fraxinus* L.
	Aspen, quaking aspen	*Populus tremuloides* Michx.
	Birch	*Betula* L.
	Blue oak	*Quercus douglasii* Hook. & Arn.
	Bristlecone pine	*Pinus aristata* Engelm.
	Butano Ridge cypress	*Hesperocyparis abramsiana* (C.B. Wolf) Bartel var. *butanoensis*
	California black oak	*Quercus kelloggii* Newberry
	California juniper	*Juniperus californica* Carr.
	California nutmeg, California torreya	*Torreya californica* Torr.
	California red fir	*Abies magnifica* A. Murr.
	California white oak	*Quercus lobata* Née
	California-laurel	*Umbellularia californica* (Hook. & Arn.) Nutt.
	Coast live oak, California live oak	*Quercus agrifolia* Née
	Cottonwood	*Populus* L.
	Cypress	*Cupressus* L.
	Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
	Elm	*Ulmus* L.
	Engelmann spruce	*Picea engelmannii* Parry ex Engelm.
	Fir	*Abies* Mill.
	Foxtail pine	*Pinus balfouriana* Grev. & Balf.
	Giant sequoia	*Sequoiadendron giganteum* (Lindl.) Buchh.
	Grand fir	*Abies grandis* (Dougl. ex D. Don) Lindl.
	Great Basin bristlecone pine	*Pinus longaeva* D.K. Bailey
	Hemlock	*Tsuga* Carrière
	Incense cedar	*Calocedrus decurrens* (Torr.) Florin
	Interior live oak	*Quercus wislizeni* A. DC.
	Jeffrey pine	*Pinus jeffreyi* Grev. & Balf.
	Juniper	*Juniperus* L.
	Laurel	*Umbellularia* (Nees) Nutt.
	Lodgepole pine	*Pinus contorta* Dougl. ex Loud.
	Maple	*Acer* L.
	Mountain hemlock	*Tsuga mertensiana* (Bong.) Carr.
	Oak	*Quercus* L.
	Pacific silver fir	*Abies amabilis* (Dougl. ex Loud.) Dougl. ex Forbes
	Pacific yew	*Taxus brevifolia* Nutt.
	Pine	*Pinus* L.
	Ponderosa pine	*Pinus ponderosa* Lawson & C. Lawson
	Red alder	*Alnus rubra* Bong.
	Redcedar	*Thuja plicata* Donn ex D. Don

Life form	Common name	Scientific name
	Redwood, coast redwood	*Sequoia sempervirens* (Lamb. ex D. Don) Endl.
	Single-leaf Pinyon	*Pinus monophylla* Torr. & Frém.
	Sitka spruce	*Picea sitchensis* (Bong.) Carrière
	Sugar pine	*Pinus lambertiana* Douglas
	Spruce	*Pinus monophylla* Torr. & Frém.
	Tanoak	*Notholithocarpus* P.S. Manos, C.H. Cannon, & S.H. Oh
	True fir	*Abies* Mill.
	Santa Cruz cypress	*Hesperocyparis abramsiana* (C.B. Wolf) Bartel var. *abramsiana*
	Santa Cruz cypress	*Hesperocyparis abramsiana* (C.B. Wolf) Bartel var. *butanoensis* (Silba) Bartel & R.P Adams
	Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
	Western juniper	*Juniperus occidentalis* Hook.
	White fir	*Abies lowiana* (Gordon & Glend.) A. Murray bis
	Western white pine	*Pinus monticola* Douglas ex D. Don
Shrubs:	Beaked hazelnut	*Corylus cornuta* Marshall
	Buckbrush	*Ceanothus cuneatus* (Hook.) Nutt.
	Bush chinquapin	*Chrysolepis sempervirens* (Kellogg) Hjelmqvis
	California blackberry	*Rubus ursinus* Cham. & Schltdl.
	California huckleberry	*Vaccinium ovatum* Pursh
	Creeping snowberry	*Symphoricarpos mollis* Nutt.
	Deerbrush	*Ceanothus integerrimus* Hook. & Arn.
	Eastern Mojave buckwheat	*Eriogonum fasciculatum* Benth.
	Hazel	*Corylus* L.
	Greenleaf manzanita	*Arctostaphylos patula* Greene
	Huckleberry oak	*Quercus vacciniifolia* Kellogg
	Himalayan blackberry	*Rubus armeniacus* Focke
	Manzanita	*Arctostaphylos* Adans.
	Mountain misery	*Chamaebatia foliolosa* Benth.
	Oceanspray	*Holodiscus discolor* (Pursh) Maxim.
	Pacific poison oak	*Toxicodendron diversilobum* (Torr. & A. Gray) Greene
	Pinemat manzanita	*Arctostaphylos nevadensis* A. Gray
	Prostrate ceanothus	*Ceanothus prostratus* Benth.
	Salal	*Gaultheria shallon* Pursh
	Scotch broom	*Cytisus scoparius* (L.) Link
	Snowbrush ceanothus	*Ceanothus velutinus* Douglas ex Hook.
	Sticky whiteleaf manzanita	*Arctostaphylos viscida* Parry
	Whitethorn ceanothus	*Ceanothus cordulatus* Kellogg
	Whiteleaf manzanita	*Arctostaphylos manzanita* Parry
	Willow	*Salix* L.

Life form	Common name	Scientific name
Forbs:	Western brackenfern	*Pteridium aquilinum* (L.) Kuhn
	Bull thistle	*Cirsium vulgare* (Savi) Ten.
	Beargrass	*Xerophyllum tenax* (Pursh) Nutt.
	Clover	*Trifolium* L.
	Giant chainfern	*Woodwardia fimbriata* Sm.
	Italian plumeless thistle	*Carduus pycnocephalus* L.
	Longbeak stork's bill	*Erodium botrys* (Cav.) Bertol.
	Maidenhair fern	*Adiantum aleuticum* (Rupr.) Paris
	Redstem stork's bill	*Erodium cicutarium* (L.) L'Hér. ex Aiton
	Spreading hedgeparsley	*Torilis arvensis* (Huds.) Link
	Thistle	*Cirsium* Mill.
	Yellow star-thistle	*Centaurea solstitialis* L.
Graminoids:	Bristly dogstail grass	*Cynosurus echinatus* L.
	Brome	*Bromus* L.
	Cheatgrass	*Bromus tectorum* L.
	Compact brome	*Bromus madritensi*s L.
	Medusahead	*Taeniatherum caput-medusae* (L.) Nevski
	Purple false brome	*Brachypodium distachyon* (L.) P. Beauv.
	Red brome	*Bromus rubens* L.
	Ripgut brome	*Bromus diandrus* Roth
	Soft brome	*Bromus hordeaceus* L.
	Wild oat	*Avena fatua* L.

Acknowledgments

None of the data presented in this report would be possible to obtain without the tireless efforts of the field crews working in California in 2006–2015. Thanks are also due to the quality assurance and information management staff who diligently maintain data integrity as well as those who contributed to the review of this report.

Metric Equivalents

When you know:	Multiply by:	To find:
Inches	2.54	Centimeters
Feet (ft)	.3048	Meters
Miles (mi)	1.609	Kilometers
Acres (ac)	.405	Hectares
Board feet	.0024	Cubic meters
Cubic feet (ft^3)	.0283	Cubic meters
Cubic feet per acre (ft^3/ac)	.06997	Cubic meters per hectare
Tons per acre	2.24	Megagrams per hectare

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