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California's Western Juniper and Pinyon-Juniper Woodlands: Area, Stand Characteristics, Wood Volume, and Fenceposts

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Abstract

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The results of a statewide inventory of western juniper and pinyon-juniper woodlands are presented. Included are statistics on area of woodland by type and ownership; area of rangeland with scattered juniper and pinyon trees; wood volume by ownership, species, and tree size; juniper fenceposts; tree and stand age distribution; stand characteristics, including overstory and understory; and a discussion of resource potential and changes in western juniper and pinyon-juniper woodland since 1945.

Keywords: Juniper, pinyon, fenceposts, forest inventory, California.

Summary

The estimated area in California of western juniper and pinyon-juniper woodlands—stands with at least 10 percent cover in tree crowns—totals 2.4 million acres. Included are 1.1 million acres in National Forests, 0.8 million acres in other public ownership mostly Bureau of Land Management, and 0.5 million in private ownership. Scattered juniper and pinyon trees in areas with less than 10 percent tree crown cover are found on 1.0 million acres of grassland and chaparral. Juniper and pinyon trees also occur on 0.2 million acres of conifer timberland and oak woodland outside National Forests and Parks. Scattered juniper and pinyon trees also are found on grassland, chaparral, timberland, and oak woodland within National Forests and Parks, but were not sampled. These areas, amounting to roughly 0.3 million acres, bring the total area of juniper and pinyon occurrence in California to about 3.9 million acres.

Western juniper and pinyon-juniper woodlands are important to many species of wildlife. These woodlands have provided numerous goods to people from prehistoric times to the present. In the past century, the range of juniper and pinyon trees has spread in many parts of the West, including California. Since the arrival of Europeans, the major use of western juniper and pinyon-juniper woodlands has been livestock grazing; in the past 40 years, extensive areas have been cleared to increase forage production. Despite this, the total woodland area has changed very little since 1945, suggesting that the spread of juniper and pinyon trees has about equaled the area cleared. The current age distribution suggests, however, that the rate of spread is decreasing.

About 73 percent of western juniper and 59 percent of pinyon-juniper stands outside National Forests are less than 100 years old. The oldest tree in 64 percent of western juniper stands and 68 percent of pinyon-juniper stands is less than 150 years old. Stands younger than 50 years make up 12 percent of the western juniper woodland and 9 percent of the pinyon-juniper woodland.

Western juniper stands contain taller trees with larger diameters on the average than do pinyon-juniper stands; but western juniper stands are not as dense. Grass cover is considerably greater in western juniper stands than in pinyon-juniper. In western juniper stands, grass is often found beneath tree crowns, but rarely beneath shrubs. In many stands, the predominant ground cover is annual grasses with cheatgrass the most common. Density of shrub cover is about the same in western juniper and

pinyon-juniper stands; 29 shrub species were found in western juniper and pinyon-juniper stands. Commonly occurring species included sagebrush, mountain mahogany, rabbitbrush, bitterbrush, blackbush, and yucca.

The total estimated wood volume in juniper and pinyon woodlands outside parks and wilderness is about 1 billion cubic feet. This includes total aboveground volume in trunks, limbs, and branch segments at least 1 foot long to a small-end diameter of 1.5 inches. Singleleaf pinyon accounts for about 50 percent of total wood volume, and western juniper accounts for 43 percent. Six other species account for the remaining 7 percent: Utah juniper, California juniper, Jeffrey pine, ponderosa pine, Oregon white oak, and interior live oak.

Main-stem tree volume totals 318 million cubic feet. This includes volume in trees 5.0 inches and larger at breast height to a 4-inch top. Singleleaf pinyon, with 50 percent of the total wood volume, has only 23 percent of the main-stem volume. Seventy percent of the total main-stem volume is in western juniper.

About 143 million fenceposts could be cut from juniper trees in western juniper and pinyon-juniper woodlands, enough to build 400,000 miles of fence. About 96 percent of these posts would be western juniper; California juniper and Utah juniper would make up the remaining 4 percent. The value of these posts, in terms of the retail price of steel or pressure-treated wooden posts they could substitute for, is about \$360 million. The high cost of cutting posts from limby juniper trees makes commercial post operations marginal, but a slight increase in the price of steel and pressure-treated wooden posts might change this. Juniper posts are commonly used by local ranchers, and this use is expected to continue. The production of posts, or a combination of posts and other products such as fuelwood and biomass, could help offset the costs of clearing woodland areas for range improvement.

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Introduction

About This Study

Juniper and pinyon woodlands in California were inventoried as part of a statewide forest resource inventory conducted in 1981-84. Although estimates of total area in juniper and pinyon woodlands had been made in previous studies (Bolsinger 1980, USDA Forest Service 1972, Wieslander and Jensen 1946), the 1981-84 study, reported here, was the first done statewide in which ground plots were installed and monumented for future location, stand and tree measurements were taken, and subordinate vegetation was recorded. The inventory was prompted by a growing list of questions about juniper and pinyon woodlands asked by land and resource managers, researchers, energy developers and policymakers: (1) Are juniper and pinyon woodlands still spreading? (2) What are the characteristics of existing juniper and pinyon stands that relate to wildlife habitat, livestock management, and vegetation control efforts? (3) How much fuelwood or woody biomass is in pinyon and juniper woodlands? (4) How many usable fenceposts might be harvested from juniper and pinyon woodlands?

Juniper and Pinyon Woodlands in the Western United States

Juniper and pinyon woodlands cover about 47 million acres in the Western United States (USDA Forest Service 1981) ranging from Texas and the Dakotas to eastern Oregon and to within a few miles of the Pacific Ocean in central California (Little 1971). Included are stands with 10 percent or more of the ground covered with the canopies of one or more of nine species of juniper (*Juniperus* L. spp.) and four species of pinyon pine (*Pinus* L. spp.). Several other tree species can be found in these woodlands, but usually in minor amounts. Over much of their range, pinyon and juniper woodlands grow between the desert or steppe of lowland areas and conifer timberland of the higher elevations. In some areas, pinyon or juniper trees are found at the same elevation as sagebrush steppe, usually on rocky or eroded terrain (Garrison and others 1977).

Juniper and Pinyon in California

Juniper and pinyon woodlands are found in many parts of California, although they are most extensive east of the Sierra Nevada and Cascade Range. Juniper and pinyon trees generally grow where annual precipitation averages between 8 and 12 inches and the frost-free season is about 120 days (Amo and Hammerly 1984, Garrison and others 1977).

In Siskiyou County and east of the Cascades and Sierra-Nevada from the Oregon border to Lake Tahoe are extensive stands of western juniper (*Juniperus occidentalis* Hook.). Although several tree species can be found in these stands on microsites and in transition zones, pinyon pine and other species of juniper are absent. At higher elevations, western juniper woodland often grades into forests of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) and Jeffrey pine (*P. jeffreyi* Grev. & Balf.) or into stands of curlleaf mountain-mahogany (*Cercocarpus ledifolius* Nutt.) (fig. 1). In Siskiyou County, and on lava flows in eastern Shasta County, western juniper intermingles with stands of Oregon white oak (*Quercus garryana* Dougl. ex Hook.), California black oak (*Q. kelloggii* Newb.), and chaparral (*Arctostaphylos* Adans spp., *Ceanothus* L. spp., *Cercocarpus betuloides* Nutt. ex T. & G., *Garrya* Dougl. spp., and *Quercus garryana* var. *breweri*



Figure 1—Western juniper stand with mountain-mahogany and scattered ponderosa pine, Modoc County.



Figure 2—Measuring a singleleaf pinyon. The sparse grass cover is typical of singleleaf pinyon sites in California.

South of Lake Tahoe on the east slopes of the Sierra Nevada, singleleaf pinyon (*Pinus monophylla* Torr. & Frem.) occurs either in pure stands or mixed with Utah juniper (*J. osteosperma* (Torr.) Little) (fig. 2). Western juniper trees are occasionally found in pinyon pine stands. Western juniper also grows in high mountain areas in the southern Sierra Nevada, where it is commonly called "Sierra juniper" (fig. 3). This high-elevation form of western juniper, recognized by Vasek (1966) as subspecies *australis*, is often found in stands of Jeffrey pine, lodgepole pine (*P. contorta* D. Don), and California red fir (*Abies magnifica* A. Murr.) or at the edge of these stands bordering meadows and rock outcrops.

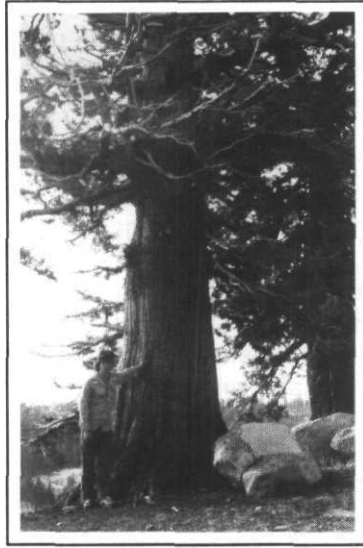


Figure 3—Sierra juniper, a subspecies of western juniper, is the largest juniper species in California. This tree is in Alpine County, at an elevation of 8,600 feet.

California juniper (*J. californica* Carr.) occurs in scattered localities on the lower west slopes of the Sierra Nevada and the east slopes of the Coast Range from Shasta County to Kern County. It is found within a few miles of the Pacific Ocean in San Luis Obispo County. California juniper occasionally grows in fairly dense pure stands, but more frequently occurs as a scattered tree in grassland, on micro sites in chaparral (*Adenostomafasciculatum* H. & A., *Arctostaphylos* spp., *Ceanothus* spp., and *Quercus* spp.), and in woodlands of blue oak (*Quercus douglasii* Hook. & Am.) and interior live oak (*Q. wislizenii* A. DC.). In southern California, California juniper is found along the edge of the desert, often associated with singleleaf pinyon, Joshua tree (*Yuccabrevifolia* Engelm. in Wats.), black bush (*Coleogyneramosissima* Torr.), creosote bush (*Larreadivaricata* Cav.), or in chaparral.

Parry pinyon (*Pinus quadrifolia* Parl.) occurs in minor amounts in southern California (Little 1971). Colorado pinyon (*Pinus edulis* Engelm.) occurs in the New York Mountains in eastern San Bernardino County (the two-needled pinyon at this location is thought by some scientists to be an atypical form of *P. monophylla* or a hybrid [Vasek and Thorne 1977]).

Use of Juniper and Pinyon Woodlands

The major use of juniper and pinyon woodlands is livestock grazing. Herbage and forage production range from near zero on **poor** sites to more than 800 pounds per acre for herbage and 300 pounds for forage on the best sites (Garrison 1977). In most areas, forage production is inversely related to tree cover, which is why the emphasis in juniper and pinyon management has been on tree removal (Clary 1974, Everett and Sharrow 1985, Jameson 1967).

Juniper and pinyon woodlands provide habitat for many animals. The western juniper-big sage-grass association, extensive in northeastern California, is used by **14** species of reptiles and amphibians, **88** species of birds, and **44** species of mammals (Elmore **1984**).

Native Americans and present residents have found juniper and pinyon woodlands to be a source of firewood, pine "nuts," and durable posts. Veneer and particleboard have been made from juniper in Arizona (Barger and Ffolliott **1972**). Hardboard has been made from western juniper chips (Frashour and Nixon **1956**), and volatile oil containing fatty and resin acids, phytosterol, and other extractives has been recovered by steam distillation from western juniper (Kurth and Ross **1954**). Other uses have included charcoal, "cedar" chests, novelty items made of sawn juniper wood, Christmas trees, Christmas wreaths and swags, and living ornamentals (Aldon and Loring **1977**, Barger and Ffolliott **1972**, Bedell **1984**).

Historical Spread of Juniper and Pinyon Woodlands

The range of juniper has spread and the density of many stands has increased in many parts of the West since the late **1800's** (Aldon and Loring **1977**, Bedell **1984**, Caraher **1978**). In California, plot data gathered for this study indicated that western juniper stands, and to a lesser degree Utah juniper and California juniper stands, have increased in density and in total area. The pinyons, heavy-seeded species, have spread less rapidly. In many areas, pinyons become established only after juniper trees have occupied the area. Junipers provide habitat for birds and small mammals that bring in pinyon seeds from distant areas and create microsites favorable to pinyon seedlings (Little **1977**). Some notable exceptions include the eastern slopes of the Sierra Nevada in Alpine County, where young singleleaf pinyon trees dot the sagebrush steppe, and occasional pure stands of singleleaf pinyon in Inyo, Kern, Tulare, and San Bernardino Counties.

The spread of juniper has been attributed to **two** major human-caused factors: heavy grazing by domestic animals in the mid-1880's to early **1900's** and fire suppression. Grazing reduced the grass cover, exposing a mineral-soil seedbed favorable to juniper establishment; fire suppression lengthened the period between wildfires, allowing juniper trees to spread (Aldon and Loring **1977**, Arno and Hammerly **1984**, Bedell **1984**, Vasek and Thorne **1977**). As plausible as the above explanation seems, other factors may be at play. Mehringer and Wigand (**1984**) found evidence in woodrat midden fossils in eastern Oregon and northern California that western juniper has advanced and retreated several times in the past 5000 years:

The fossil records show that the persistent recent advance of western juniper. . . is not unique to the historic grazing by cattle, sheep and horses, and reduced fire frequencies. In fact, the rate and degree of change in the comings and goings of western juniper over the late Holocene are equal to or greater than those seen over the past hundred years.

In their study, Mehringer and Wigand suggest that climatic cycles were possibly the most important factor in the expansion and contraction of the range of western juniper.

Whatever the cause, the spread of juniper in recent decades has caused concern among range managers and has been the impetus for numerous research studies and vegetation control projects (Aldon and Loring 1977; Bedell 1984; Clary 1974; Everett and Sharrow 1985; Gifford and Shaw 1973; Jameson 1967; Little 1977; USDA Forest Service 1972, 1981; Young 1984). Detrimental effects of juniper differ by site and stand density but can be generalized as follows: Juniper trees use enormous amounts of water, including much of the winter-accumulated soil moisture needed by forage plants (Jeppesen 1978). Both amount and nutritive value of forage plants in juniper stands are reduced. The development of bare soil in juniper stands, coupled with the water-channeling effect of juniper's branching habit result in accelerated erosion. In some areas, the advancement of juniper is thought to have lowered the water table and reduced stream flow (Buckhouse 1984, Miller 1984).

Whether or not the positive aspects of juniper and pinyon woodland—such as its scenic beauty, potential for various products, and value to wildlife—offset its undesirable characteristics, cannot be answered objectively. Factual information can, however, reveal alternatives that may otherwise be unknown and help guide policy-makers to sound decisions on resource allocation. The information in this report should be useful toward that end.

Methods and Reliability of Estimates

Most of the information in this report is from three major sources of data:

1. For **National Forests**, data were provided by the USDA Forest Service Regional Offices at Ogden, Utah, and San Francisco, California; and the Supervisor's Offices of the various National Forests (listed on page 11).
2. For **parks and other reserved areas outside National Forests**, information was provided by park supervisors and agency heads (reserved areas are listed on page 11).
3. For **lands other than National Forests, parks, and other reserved areas**, information was gathered by personnel from the USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon, with assistance from the Intermountain Research Station, Ogden, Utah.

For National Forests, area information was compiled from vegetation type maps prepared during standard resource inventories. Aerial photographs and satellite imagery were used with elevation and topographical information to determine vegetation type. Typing was done by persons familiar with local vegetation conditions. Two broad types were recognized: (a) western juniper and (b) pinyon-juniper, the latter including all juniper and pinyon stands except those in which western juniper dominated. Western juniper and pinyon-juniper types were separated by geographical location rather than by recognition on photographs and satellite imagery. Ground samples were not taken, and species of trees and subordinate vegetation were not recorded.

Information on wood volume and fenceposts in juniper and pinyon types in National Forests was not collected. Approximations were made by broad type based on detailed information collected in stands outside National Forests.

Specific statements of reliability cannot be made for the National Forest data. Type-mapped areas carry no sampling error but are subject to errors in type identification, type-line placement, and determination of area by type. A check of the classification for two National Forests indicated that mapped types were correctly identified 85 per cent of the time (for details on the classification procedures contact USDA Forest Service, 630 Sansome Street, San Francisco, CA 94111).

For parks and other reserved areas outside National Forests, area by type was determined either by the park agencies or through agency contracts with consultants; various methods were used. As in National Forests, western juniper type was separated from pinyon-juniper by geographic location. No information was collected on tree species or other vegetation. Because tree cutting is generally not permitted in parks, no approximations were made of wood volume or number of fenceposts. The reliability of area estimates in parks and reserved areas is thought to be comparable to that for area estimates in National Forests.

For lands other than National Forests and parks and other reserved areas outside National Forests, the area in western juniper and pinyon-juniper woodlands was determined as part of a statewide forest inventory. Cochran's (1977) double sampling for stratification was used. The primary sample consisted of aerial photo points located as follows: A computer-generated grid dividing the land into squares 0.85 mile on a side was projected over the State. Within each square, a randomly located point was plotted on a U.S. Geological Survey quadrangle map and referenced to the Universal Transverse Mercator (UTM) coordinate system. Each point was transferred to an aerial photograph and classified into forest and nonforest. Forest points were further classified into timberland, woodland, and chaparral; these were classified into broad condition classes and vegetation types (such as oak woodland and juniper and pinyon woodland). Points in nonforest and in chaparral with scattered trees were classified by tree density and broad species group—timber conifer, hardwood, and juniper/pinyon. Points in timberland, woodland, and chaparral were classified by ownership group from county records.

Statewide and outside National Forests and parks, 85,174 aerial photo sample points were classified. Either juniper or pinyon trees, or both, were present on 4,359 of these:

Vegetation type with juniper or pinyon present	Aerial photo points
Juniper and pinyon woodland	2,547
Hardwood woodland	20
Chaparral	80
Grassland and barren (for example, lava flows)	1,712

The secondary sample, a subsample of about 1 out of 16 of the aerial photo points, was selected on a systematic grid with a 3.4-mile interval. Each selected point was examined to determine the accuracy of the aerial photo classification. A subsample of the 3.4-mile-interval points was selected for establishing ground plots on which trees and vegetation were tallied. A total of 194 plots in juniper and pinyon woodland were classified:

Photo class verification only	135
Tree and vegetation tally	59
	<hr/>
Total ground plots	194

Plots in western juniper stands consisted of three to five subplots distributed over a 5-acre area; trees were tallied on a series of fixed- and variable-radius plots with an outer limit of 55.8 feet (slightly greater than that of a one-fifth-acre circular plot). For trees 1.0 inch and larger, d.b.h. (diameter at breast height) was measured, and total height was determined. Total volume and volume from a 1-foot stump to a 4-inch top were computed for trees 5.0 inches d.b.h. and larger by using volume equations developed from felled and sectioned western juniper trees in central Oregon and north-eastern California (Chittester and MacLean 1984).

In stands of pinyon, Utah juniper, and California juniper, one plot was established at each location. Each plot was a series of concentric fixed-radius circles having a maximum radius of 52.7 feet (one-fifth acre). Pinyon pine, Utah juniper, and California juniper, unlike western juniper which is often straight and single-stemmed, are usually crooked, forked, and multistemmed. Traditional volume-estimation techniques designed for trees with a well-defined main bole do not work for these woodland species often resembling large bushes. A system developed by Born and Chojnacky (1985) was used to estimate wood volume in these species. Briefly, the system entailed measuring tree diameter at the root collar (usually at ground level) and total height; determining the volume in segments of stems, forks, limbs, and branches; and summing the volume for all segments. Trees with diameters at root crown of 3.0 inches and larger were measured. The minimum segment size was 1 foot long to a 1-1/2-inch small-end diameter with a midpoint diameter of at least 2 inches. Detailed segment measurements were taken on a subsample of trees. Volumes calculated for these trees were used to develop a simple regression model for predicting volume in all trees measured in the inventory. The predictor variables used were total tree height and diameter at root collar.

Measurements were taken on a sample of western juniper trees by using both methods described above. These measurements were used to develop a regression equation to predict total tree volume in western juniper trees.

For each western juniper, Utah juniper, and California juniper tree tallied, the number of straight sections suitable for fenceposts was estimated (detailed specifications are in the section on fenceposts, page 26). Other information gathered on all trees tallied included tree age, tree damage, crown class, and crown ratio. At each plot, total percentage of ground cover was estimated for these plant groups: trees, shrubs, forbs and grasses. In addition, shrubs were identified by species. Little (1979) was the authority for trees; Munz and Keck (1970) for other plants.

All aerial photo sample points were carefully marked on aerial photographs, and ground plots were "monumented" with stakes and metal tree markers. Azimuth and distance readings from all tree markers to stakes were recorded so that each plot and each tree on each plot can be relocated for remeasurement and reclassification. These samples can become the basis for monitoring trends in juniper and pinyon woodlands in the future. After most of the sample plots in juniper and pinyon woodlands had been established, responsibility for assessing pinyon and juniper resources was transferred to the USDA Soil Conservation Service.¹ Whether or not the plots established by the Forest Service will be used to monitor juniper and pinyon woodlands in California remains to be seen.

Statistical Accuracy

Estimates of woodland area, volume in trees, and numbers of fenceposts were obtained by sampling and are subject to sampling error. These estimates and their associated confidence intervals (68-percent probability) are shown below:

Woodland type and ownership	Area	Confidence Interval	
	Thousand acres	Percent	
Western juniper:			
Public	400	+25	±6.2
Private	315	±31	±9.8
Total	715	±42	±5.9
Pinyon-Juniper:			
Public	353	±32	±9.1
Private	148	+12	±8.1
Total	501	±38	±7.6
Total woodland	1,216	±52	±4.2

¹ Peterson, Max; Meyers, Peter, 1983. Forest Service—Soil Conservation Service agreement on inventory and technical assistance. Washington DC: U.S. Department of Agriculture, Forest Service. 4 p. On file with: Soil Conservation Service, Davis, California.

The above agreement was amplified and responsibilities for inventorying specific vegetation types were clarified in: Shaw, Robert R. 1987. Supplemental materials for conducting the 1987 national resources inventory. National Bulletin 290-7-4. Washington DC: U.S. Department of Agriculture, Soil Conservation Service. 5 p. On file with: Pacific Northwest Research Station, P.O. Box 3890, Portland, Oregon 97208-3890.

Species	Total tree volume	Confidence interval	
	<i>Million cubic feet</i>	<i>Thousands</i>	<i>Percent</i>
Western juniper	222.5	k18.5	k8.3
Utah juniper	17.5	k9.7	f55.4
California juniper	9.3	k6.8	±73.1
Singleleaf pinyon	258.0	k74.0	k28.6
Jeffrey pine	6.0	k3.0	k50.0
Ponderosa pine	4.1	k2.9	k70.7
Oregon white oak	2.0	k2.0	f100.0
Interior live oak	1.2	k1.2	k100.0
All species	520.6	k81.0	k15.5

Fencepost category	Number of posts	Confidence interval	
	<i>Thousands</i>	<i>Thousands</i>	<i>Percent</i>
Round	13,197	+2,200	k16.7
Wedge-shaped:			
Splittable or sawable	66,595	+8,122	k12.2
Sawable only	1,474	+531	k36.0
Total	81,266	+8,614	k10.6

Accuracy of Measurements and Classification

Data for this study were collected by scientists and technicians who had several years of experience in aerial photo interpretation, land classification, forest measurement, and plant identification. Tree measurements in western juniper woodland were taken by personnel from the Pacific Northwest Research Station familiar with the Station's inventory system. In pinyon-pine, Utah juniper, and California juniper woodland, tree measurements were taken by personnel from the Intermountain Forest and Range Experiment Station, Ogden, Utah, who used tree segmentation techniques developed by Born and Chojnacky (1985) for intermountain woodland species. Local experts assisted in identifying uncommon plants. A subsample of plots was selected and revisited as part of a formal quality-control system. Accuracy of plot location was checked, all measured and classified items were remeasured or reclassified, and identification of plants was verified. These measures are thought to have kept errors to a minimum (for definitions of terms used in this report see "Terminology," page 33).

Area of Juniper and Pinyon

Western Juniper and Pinyon-Juniper Woodlands Total 2.4 Million Acres

The total estimated area in western juniper and pinyon-juniper woodlands in California is 2,372,000 acres (table 1). Included are areas where crowns of juniper or pinyon trees, or both, cover at least 10 percent of the ground or areas that had such cover before trees were removed or killed (unless all trees were removed or killed, in which case the area was classified as nonforest). Western juniper woodland amounts to 1,284,000 acres, 54 percent of the total. Most of the western juniper woodland is in Lassen, Modoc, Shasta, and Siskiyou Counties in northeastern California. The remaining 1,089,000 acres (46 percent)—called pinyon-juniper in this report—include

Table I—Area of western juniper and pinyon-juniper woodland, by ownership and reserved status, California, 1985^a

Ownership and reserved status	Woodland		
	Western juniper ^b	Pinyon-juniper ^c	Total
<i>Thousand acres</i>			
National Forest:			
Reserved	10	28	38
Unreserved	540	528	1,068
Total	550	556	1,106
Other public:			
Reserved	20	30	50
Unreserved	400	353	753
Total	420	383	803
Private:			
Reserved	0	0	0
Unreserved	315	148	463
Total	315	148	463
All ownerships:			
Reserved	30	58	88
Unreserved	1,255	1,029	2,284
Total	1,285	1,087	2,372

^a Included as reserved are parks, wilderness areas, natural areas, and land purchased by The Nature Conservancy.

^b Stands dominated by western juniper.

^c Stands dominated by pinyon pine or Utah juniper or California juniper, or combinations of the above.

pure or mixed stands of singleleaf pinyon, Utah juniper, California juniper, and minor amounts of Colorado pinyon and Parry pinyon. Pinyon-juniper is found south of the western juniper woodland but may occasionally include a few western juniper trees.

National Forests contain 1,106,000 acres, 47 percent of the total area of juniper and pinyon woodlands. Thirty-eight thousand acres of this are in wilderness areas, including 10,000 acres of western juniper and 28,000 acres of pinyon-juniper. The following tabulation shows the total area of western juniper and pinyon-juniper woodland by National Forest:

National Forest	Western juniper	Pinyon-juniper
	----- Acres -----	
Angeles	0	21,648
Inyo	0	359,500
Klamath	5,000	0
Lassen	60,044	114
Los Padres	0	48,700
Modoc	469,535	0
Plumas	7,924	0
San Bernardino	0	66,812
Shasta	7,347	0
Stanislaus	64	0
Tahoe	Trace	1,600
Toiyabe	0	58,103
	<hr/>	
Total	549,914	556,477

In public ownerships other than National Forests are 803,000 acres of western juniper and pinyon-juniper woodland, or 34 percent of the total in California. About 90 percent of this is administered by the U.S. Department of the Interior, Bureau of Land Management: 6 percent is in parks and other reserved areas (see following list); and the balance is on military, Native American, miscellaneous Federal, State, county, and municipal lands. Private owners hold 463,000 acres or 19 percent.

Resewed area	Western junlper	Pinyon-juniper
	----- Acres -----	
Lava Beds National Monument	13,800	0
Devil's Post Pile National Monument	100	0
Death Valley National Monument	0	29,000
Yosemite National Park	6,100	0
Anjurnowi Lava Spring State Park	30	0
Hartford Springs County Park	0	75
Granite Mountain (University of California)	0	400
Burns Pinyon Ridge (University of California)	0	100
Bennett Juniper Reserve (Nature Conservancy)	0	4
	<hr/>	
Total	20,030	29,579

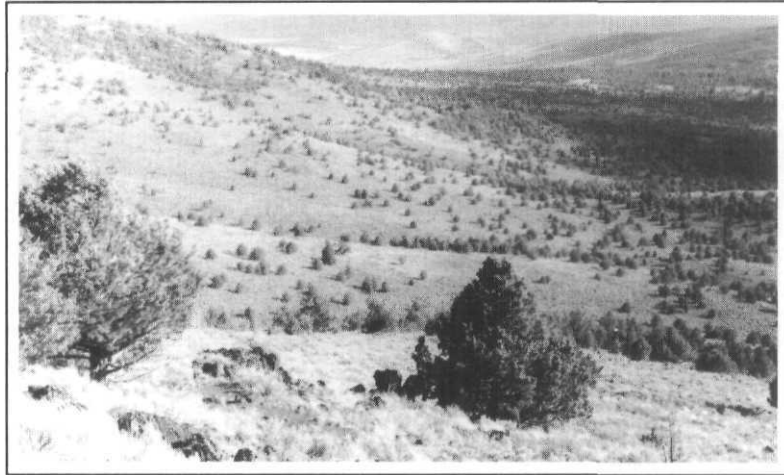


Figure 4—Density of western juniper in this Lassen County landscape grades from fewer than 5 trees per acre to 60 percent crown closure. Woodland areas have at least 10 percent crown closure; savannas less than 10 percent. In California, juniper and pinyon woodlands total 2.4 million acres, savannas about 800,000 acres.

Juniper and Pinyon Savanna

By definition, woodland areas are at least 10 percent covered by tree crowns. Within the range of juniper and pinyon are extensive areas where trees grow too far apart to make up 10 percent cover (fig. 4). Sparsity of stands may be caused by low precipitation, plant competition, history of use by animals, soil characteristics such as depth, rockiness, and pH, singly or in combination. These areas of sparse tree cover, often called savannas, are classified as nonforest. For wildlife habitat and aesthetic considerations, the savannas are quite different from the extensive treeless steppes of nearby regions. In some areas, these savannas may represent the beginning stage of juniper or pinyon encroachment into rangeland. They are of special interest to range managers.

For lands outside National Forests, area of juniper and pinyon savanna was estimated by tree density classes. At each aerial photo sample location, trees were counted within a circular 5-acre plot. Tree species were not identified on aerial photographs, but were assigned according to the geographic location of the photo points. The total area of juniper and pinyon savanna was estimated to be 797,000 acres. About three-fourths of this area was occupied by western juniper; 43 percent had one to five trees per 5-acre plot (see table 2). Estimates of juniper and pinyon savanna in National Forests are not available. National Forests are generally at higher elevations than other ownerships and therefore have proportionately less land in the savanna zone.

Table 2—Area of juniper and pinyon savanna outside National Forests and parks and other reserved areas, by dominant species and tree density class, California, 1985

Dominant species	Tree density class			Total
	1-5 trees per 5 acres	6-25 trees per 5 acres	26 trees per 5 acres to 9% cover	
	<i>Thousand acres</i>			
Western juniper	226	232	134	592
Pinyon or Utah juniper	101	69	9	179
California juniper	17	7	2	26
Total	344	308	145	797

Juniper and Pinyon Trees in Chaparral

Outside National Forests, scattered juniper trees were found on 194,000 acres of chaparral. In northern California, western juniper trees were found on 49,000 acres of chaparral types. In southern California and on the interior slopes of the Coast Range, California juniper was found on 145,000 acres of chaparral, usually on microsites. Utah juniper and pinyon trees were not found in chaparral outside National Forests. Parry pinyon occurs in chaparral in southern California (Griffin and Critchfield 1972); its range there is extremely limited, and it was not tallied on any sample plots.

Juniper and Pinyon Trees In Conifer Timber Stands

Outside National Forests and parks, western juniper trees were found on 115,000 acres of conifer timber stands, including 68,000 acres of ponderosa pine and Jeffrey pine and 47,000 acres of mixed conifer. In northeastern California, junipers were found near the lower elevational range of the timber zone. In the central and southern Sierra Nevada, they were found near the upper elevational range of conifer timber species. Singleleaf pinyon was found in about 8,000 acres of Jeffrey pine stands near the lower forest fringe.

Juniper Trees in Oak Woodland

Western juniper trees were found on 56,000 acres of Oregon white oak woodland outside National Forests and parks in northeastern California. California juniper was found on 67,000 acres of blue oak woodland in the foothills bordering the Sacramento and San Joaquin Valleys.

Juniper or Pinyon Trees Occur on at Least 3.6 Million Acres

The total estimated area in which juniper or pinyon trees, or both, are known to occur is 3,591,000 acres, as shown in the following tabulation:

Category	Thousand acres
Juniper and pinyon woodland	2,373
Juniper and pinyon savanna	797
Juniper and pinyon trees in chaparral	194
Juniper and pinyon trees in conifer timber stands	115
Juniper trees in oak woodland	112
Total area of juniper and pinyon occurrence	3,591

The total estimated area of juniper and pinyon woodland shown above—2,373,000 acres—includes all ownerships. The estimates of area in juniper and pinyon savanna, juniper and pinyon trees in chaparral, pinyon and juniper trees in timber stands, and juniper trees in oak woodland do not include National Forests and parks, for which information is not available. National Forests contain about 35 percent of the chaparral in the State, some of which has inclusions of juniper; and National Forests and several parks contain extensive areas of high-elevation forest in which Sierra juniper occurs. These areas could easily bring the total area of juniper and pinyon occurrence in California to 3.8 to 3.9 million acres.

Little Change in Area of Juniper and Pinyon Since 1945

The estimated area of juniper and pinyon pine types in California in 1945 was 3.2 million acres (Wieslander and Jensen 1946). Included were areas at least 5-percent covered with the crowns of junipers or pinyon pines (western juniper and pinyon-juniper types were not separated in 1945). The 3.2 million acres is identical to the 1985 area of juniper and pinyon woodlands plus juniper and pinyon savanna outside National Forests. The current area in savanna in National Forests and parks is unknown but would bring the total up to some number greater than 3.2 million acres. Junipers have been cleared in numerous range improvement projects during the past several years (Young 1984) (fig. 5). A comparison of the 1945 and 1988 inventories would suggest that clearings have not quite kept up with the spread of juniper and pinyon.

Characteristics of Western Juniper and Pinyon-Juniper Stands

Summarized in this section are characteristics of juniper and pinyon stands outside National Forests, as determined from sample plots.

Stand Age

Age was determined for sampled tree in each stand measured, usually from counts of growth rings on increment cores. In stands where tree cutting had recently occurred, ring counts from stumps were applied to trees of similar size and stage of development. Age for all trees over 200 years was recorded as "200-plus." For many old trees, exact age was impossible to determine because of hollow or rotten boles and deformities. Two or more age classes were represented in many stands, although in all stands sampled, the majority of the trees could be grouped into 50-year classes.

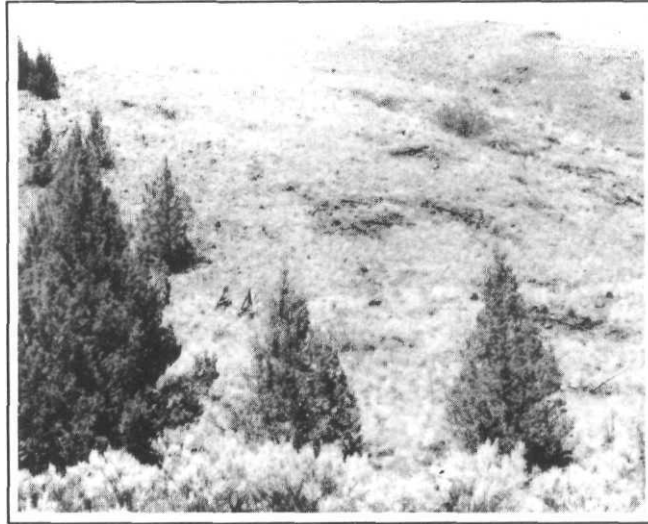


Figure 5—Recent clearing in western juniper. The pointed crowns indicate young trees. Since 1945, the spread of juniper and pinyon has equaled or surpassed the area cleared.

Table 3—Percentage of area in western juniper and pinyon-juniper woodland outside National Forests and parks, by age of stand and oldest tree, California, 1985

Woodland type and age component	Percentage of area by age group					Total
	1-49 years	50-99 years	100-149 years	150-199 years	200+ years	
	<i>Percent</i>					
Western juniper:						
Stand age	12	61	6	9	12	100
Oldest tree in stand	3	46	15	18	18	100
Pinyon-juniper:						
Stand age	9	50	18	9	14	100
Oldest tree in stand	9	27	32	14	18	100

Most Stands Younger Than 100 Years

About 73 percent of western juniper stands and 59 percent of pinyon-juniper stands were less than 100 years old. Scattered older trees were present in 43 percent of the western juniper stands that were less than 100 years old and in 39 percent of the pinyon-juniper stands less than 100 years old. Twelve percent of western juniper and 14 percent of pinyon-juniper stands were 200 years old or older. The oldest tree in 64 percent of all western juniper stands and in 68 percent of pinyon-juniper stands was **less** than 150 years (see table 3).

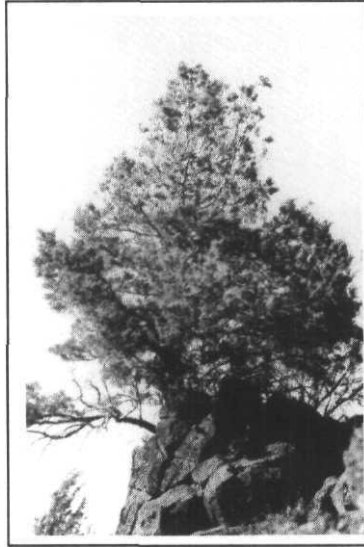


Figure 6—Ridgetop trees on rocky, fireproof sites were the seed sources for extensive stands of young western juniper in northeastern California.

The relatively small number of old trees in species able to live several hundred to a thousand years (Arno and Hammerly 1984, Young 1984) suggests that either the species have been spreading or something happened 100 to 200 years ago to reduce their numbers and since then they have reestablished themselves. Evidence exists of both situations: Pinyon stands in the mining districts near the California-Nevada border were heavily cut for mine timbers, charcoal, and firewood in the mid-to late-1800's (Vasek and Thorne 1977). Indication of previous occupancy by pinyon and juniper stands often can be seen in old stumps, remains of downed trees, standing snags, and residual patriarchs. Such areas seem to be less common than those having no evidence of former occupancy by juniper or pinyon trees. Historical records, early photographs, and long-term ecological studies indicate that pinyon or juniper trees were rare to absent before the mid-1800's or early 1900's in many areas where they are now common (Aldon and Loring 1977, Bedell 1984, Caraher 1978). Data gathered in the current inventory also indicated that many stands have appeared within the past 100 years; for example, several western juniper stands scattered over a 2,000-square-mile area in Lassen and Modoc Counties were less than 100 years old. A surprisingly large number of trees in this vast area were almost exactly the same age—73 years in 1984 (based on ring counts of increment cores to which additional years were added to account for years required to reach the height on trees where cores were taken). Except for a few trees on rocky ridges, older trees were not found in these stands (fig. 6).

Juniper and Pinyon
Advancement
Decreasing?

Table 3, above, shows that although stands less than 100 years old make up 73 percent of western juniper woodland and 59 percent of pinyon-juniper woodland, stands less than 50 years old make up only 12 percent of western juniper woodland and 9 percent of pinyon-juniper woodland. This suggests that the rate of advancement of

these woodland types has decreased. This could be a result of range management practices in recent decades or climatic changes; or perhaps pinyon and juniper have occupied most of the places where they are able to grow.

Stand Size and Density

In each stand sampled, tree diameters and heights were measured, seedlings were counted, and percentage of ground covered by live tree crowns was estimated. Tables 4 and 5 show detailed size and density characteristics for western juniper and pinyon-juniper stands.

Table 4—Stand characteristics in western juniper woodland outside National Forests and parks and other reserved areas, California, 1985

Stand characteristic	Stand age group				Average
	0-49 years	50-99 years	100-149 years	150+ years	
Quadratic mean diameter (inches)	9.4	10.7	15.4	16.1	12.7
Basal area per acre (square feet)	20.2	22.0	58.2	56.5	32.4
Number of trees per acre by d.b.h. class:					
Less than 1.0 inch; 6 + inches high	5	21	9	2	14
1.0-4.9 inches	12	10	12	8	10
5.0-10.9 inches	23	17	15	15	17
11.0-20.9 inches	7	7	15	14	10
21.0 inches and larger	0	1	3	3	2
All diameter classes	47	56	54	42	53
Average tree crown cover (percent)	15	21	16	13	18
Average height of dominant trees (feet)	26	25	29	33	27
Average shrub cover (percent)	19	30	21	23	26
Average grass cover (percent)	33	24	35	32	28

Table 5—Stand characteristics in pinyon-juniper woodland outside National Forests and parks and other reserved areas, California, 1985

Stand characteristic	Stand age group				Average
	0-49 years	50-99 years	100-149 years	150+ years	
Quadratic mean diameter (inches):					
Measured at root collar	7.2	12.8	13.7	18.9	13.6
Measured at breast height	4.2	9.4	10.3	15.5	10.3
Basal area per acre (square feet):					
Measured at root collar	12	64	108	183	91
Measured at breast height	4	35	62	123	54
Number of trees per acre by root collar diameter class:					
Less than 3.0 inches; 6 inches + high	8	9	57	60	29
3.0-8.0 inches	32	42	55	22	40
8.1-13.9 inches	5	18	22	16	17
14.0-23.9 inches	5	10	16	30	15
24.0 inches and larger	0	2	13	26	9
All diameter classes	50	81	163	154	110
Percentage of crown cover	12	18	25	27	21
Average height of dominant trees (feet)	13	18	30	29	22
Average shrub cover (percent)	52	23	29	49	32
Average grass cover (percent)	35	16	2	4	12

Western juniper trees on the average are larger in diameter and taller than other junipers and pinyons (fig. 7). The quadratic mean diameter of all western juniper stands sampled averaged 12.7 inches, compared with 10.3 inches for pinyon-juniper (diameters of pinyon-juniper measured at root collar were converted to breast-height equivalents) (fig. 8). Western juniper stands averaged 27 feet tall, compared with 22 feet for pinyon-juniper.

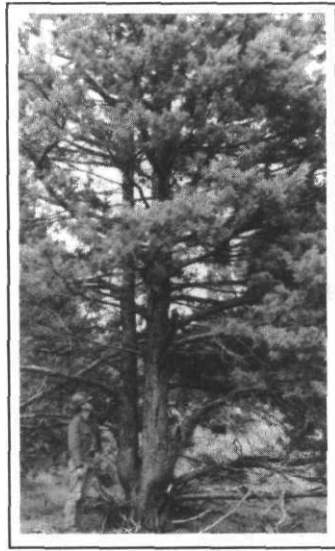


Figure 7—Western juniper trees are often taller and straighter than other species of juniper in the West. This tree is in Lassen County.

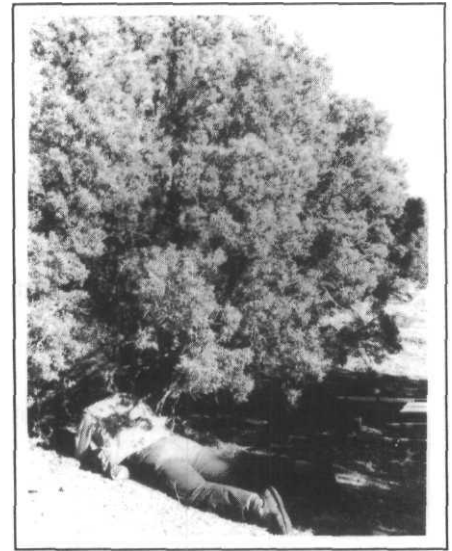


Figure 8—Utah juniper trees are often short and bushy and are difficult to measure. Grass cover is usually sparse in stands with Utah juniper.

The largest western juniper tree measured in the inventory was 56.7 inches d.b.h. This tree, growing in eastern Lassen County, was only **23** feet tall. Many taller ones were measured, including one in Modoc County that was **48** feet. The largest western juniper on record is **152.8** inches in diameter and **86** feet tall and grows in the Stanislaus National Forest. It is also the largest juniper of any species on record in the United States (Hunt **1986**).

The largest singleleaf pinyon measured in the inventory was 65.7 inches at root collar (it was not measurable at breast height) and **49** feet tall. It was found in Tulare County. On a plot in Kern County, a taller singleleaf pinyon was **59** feet tall, **40.2** inches in diameter at the root collar, and **38.2** inches at breast height. These trees are nearly as large as the record singleleaf pinyon, found in Nevada. That tree is **44.2** inches d.b.h. and 53 feet tall (Hunt **1986**). Note: Although singleleaf pinyon is typically short and shrublike, in some canyons in California it develops into a tall, straight tree with a form resembling that of ponderosa pine.

The largest Utah juniper measured in the inventory was **69.1** inches in diameter at root collar and **34** feet tall. The record tree is in Utah; it is **73.8** inches d.b.h. and 50 feet tall. The largest California juniper measured in the inventory was **43.2** inches at root collar and **15** feet tall. The record tree—in Colusa County—is **29.9** inches d.b.h. and **33** feet tall (Hunt **1986**).

Stand and Tree Height

On plots outside National Forests, most western juniper and pinyon-juniper stands were less than 40 feet tall. The mode in stand height (average height of the 15 tallest trees on a plot) was 21-30 feet in western juniper stands, and 11-20 feet in pinyon-juniper stands:

Woodland type	Percent of area by stand height (average of 15 tallest trees)				
	Less than 10 feet	11-20 feet	21-31 feet	31-40 feet	41 feet plus
	Percent				
Western juniper	0	21	49	27	3
Pinyon-juniper	14	41	18	23	4

Although trees in western juniper stands are on the average larger in diameter and taller, pinyon-juniper stands tend to be denser with greater average basal area per acre, more trees, and greater average crown cover.

Shrub and Grass Cover

As shown in tables 5 and 6, shrub cover in pinyon-juniper stands averaged 32 percent, similar to the 26 percent found in western juniper stands. In both types, shrubs usually occurred between rather than under tree crowns. In effect, tree cover and shrub cover are additive. Total woody plant cover (trees plus shrubs) averaged **44** percent in western juniper and 55 percent in pinyon-juniper. Grass cover was considerably denser on average in western juniper stands: 28 percent, compared with 12 percent in pinyon-juniper (see figs. 2 and 8). Grass covered less than 10 percent of the ground in 67 percent of the pinyon-juniper stands but did so in only 12 percent of the western juniper stands. The majority of the pinyon-juniper stands in California consist of singleleaf pinyon and Utah juniper. Everett and Sharrow (1985) found that stands of these **two** species in western Nevada also have very sparse grass cover: fully stocked stands on north and west slopes had a tree-to-grass cover ratio of 28:3 and 61:2, respectively. A similar ratio was found in California in stands 100 years old and older—26:3. Everett and Sharrow found that in western Nevada **27** acres of fully stocked pinyon-juniper woodland on north aspects and 42 acres on west aspects provide only one animal unit month of forage; but tree removal increased forage productivity 386 percent on north aspects and 840 percent on west aspects.

In western juniper stands in California, a weak negative correlation of grass cover to percentage of tree cover was found ($r = -0.24$), indicating no significant relation. The negative correlation of grass cover to shrub cover was better ($r = -0.51$). Shrubs and trees combined gave a negative correlation somewhat poorer than shrubs alone ($r = -0.47$). This was because grass—especially Idaho fescue (*Festuca idahoensis* Elmer)—was often found under tree crowns but seldom under shrubs. In some stands, grass cover was heavier under juniper crowns than in openings between trees. To some extent, this was because livestock could not get through the dense juniper branches to eat the grass. Grass cover alone may not be the best gauge of forage value. Everett and Sharrow (1985) found that digestibility and nutrient content of grass in pinyon-juniper stands increases after tree removal.

Table 6—Occurrence of shrub species in western juniper and pinyon-juniper woodland outside National Forests and parks and other reserved areas, California, 1985

Species	Western juniper	Pinyon-juniper
	<i>Percent of area</i>	
<i>Adenosfoma fasciculatum</i> H. & A.	0	4
<i>Artemisia arbuscula</i> Nutt.	3	0
<i>Artemisia fridentata</i> Nutt.	66	61
<i>Atriplex canescens</i> (Pursh) Nutt.	0	4
<i>Bernardia incana</i> Mort.	0	4
<i>Ceanothus cordulatus</i> Kell.	4	0
<i>Ceanothus cuneatus</i> (Hook.) Nutt.	2	0
<i>Ceanothus leucodermis</i> Greene	4	0
<i>Cercis occidentalis</i> Torr. ex Gray.	2	0
<i>Cercocarpus betuloides</i> Nutt. ex T. & G.	10	9
<i>Cercocarpus ledifolius</i> Nutt.	18	4
<i>Chrysothamnus</i> Nutt. spp.	14	17
<i>Coleogyne ramosissima</i> Torr.	0	22
<i>Ephedra</i> L. spp.	0	13
<i>Fremonodendron californicum</i> (Torr.) cov.	0	9
<i>Garrya</i> Dougl. spp.	2	0
<i>Haplopappus</i> Cass. spp.	4	0
<i>Holodiscus microphyllus</i> Rydb. Rehd	0	4
<i>Larrea divaricata</i> Cav.	0	4
<i>Prunus subcordata</i> Benth.	4	0
<i>Purshia glandulosa</i> Curran.	0	4
<i>Purshia fridentata</i> (Pursh) DC	28	17
<i>Quercus palmeri</i> Engelm.	0	4
<i>Quercus furbinella</i> Greene	0	9
<i>Rhus trilobata</i> Nutt. ex T. & G.	2	0
<i>Ribes</i> L. spp.	24	4
<i>Rosa</i> L. spp.	2	0
<i>Symphoricarpos</i> Duhamel spp.	0	4
<i>Yucca</i> L. spp.	0	17

Shrub and Grass Species As shown in table 6, *Artemisia fridentafa* Nutt. was the most prevalent shrub species in both western juniper and pinyon-juniper woodland; it was found in more than 60 percent of both types. Other shrubs frequently found on plots in western juniper included *Cercocarpus ledifolius*, *Chrysothamnus* Nutt. spp., *Purshia tridentata* (Pursh) DC., and *Ribes* L. spp. In pinyon-juniper stands, commonly occurring shrubs on plots included *Chrysothamnus* spp., *Coleogyne ramosissima*, *Ephedra* L. spp., *Purshia tridentata*, and *Yucca* L. spp.

Numerous grass species were found in both western juniper and pinyon-juniper woodland. Grasses in stands sampled were not consistently identified by species. Among the perennial grasses observed in western juniper stands were *Agropyron spicatum* (Pursh) Scribn. & Sm., *Elymus* L. spp., *Fesluca idahoensis*, *Poa* L. spp., *Sitanion hystrix* (Nutt.) J.G. Sm., and *Stipa* L. spp. In many stands, annual grass cover exceeded that of perennial species. Most common was *Bromus tectorum* L. Other annual grasses in western juniper stands sampled were *Bromus brizaeformis* F. & M., *Bromus mollis* L., and *Fesluca* L. spp. (several species of annual fescue, some of which have also been classified as the separate genus *Vulpia* Rydb. [Hitchcock and Cronquist 19781). *Aira caryophyllea* L. and *Bromus rigidus* Roth are annual grasses found where western juniper woodland intermingles with Oregon white oak woodland in northern California.

Grass cover in pinyon-juniper stands, though sparser than in western juniper stands, is comprised of many species. Many genera found in western juniper stands were found in pinyon-juniper—often represented by different species. Other common genera include *Aristida* L., *Bouteloua* Lag., *Hilaria* HBK, and *Muhlenbergia* Schreb.

Ground cover in forbs averaged less than 5 percent in both western juniper and pinyon-juniper stands. The densest cover in forbs recorded was 16 percent. Forb cover can vary weekly during the growing season. Some ephemeral forbs that are quite showy in June are often undetectable by August. Each plot was visited only once between May and November; for this reason, the forb cover recorded may not be indicative of stand potential.

Tree Volume and Fenceposts in Western Juniper and Pinyon-Juniper Woodlands

Total Tree and Main-Stem Volume

The total estimated tree volume in all species in western juniper and pinyon-juniper woodlands outside parks and wilderness areas in California is about 1 billion cubic feet. This includes wood and bark in segments at least 1 foot long to a small-end diameter of 1.5 inches, in trees 3.0 inches and larger in diameter at root collar (about 1 inch d.b.h.). Main-stem volume in trees 5.0 inches d.b.h. and larger from a 1-foot stump to a 4-inch top (of central stem) outside bark is estimated to total 318.2 million cubic feet, less than one-third of total tree volume. About 48 percent of total tree volume is in National Forests, 33 percent is on other public lands (mostly Bureau of Land Management), and 19 percent is on privately owned lands (see table 7).

Table 7—Total tree and main-stem volume in western juniper and pinyon-juniper woodland outside parks and other reserved areas by ownership group, California, 1985^a

Kind of volume and woodland type	Ownership			Total
	National Forest	Other public	Private	
<i>Million cubic feet</i>				
Total tree:				
Western juniper	173.6	144.9	85.3	403.8
Pinyon-juniper	307.2	182.8	107.6	597.6
Total	480.8	327.7	192.9	1,001.4
Main-stem:				
Western juniper	95.5	80.4	47.3	223.2
Pinyon-juniper	49.2	28.8	17.0	95.0
Total	144.7	109.2	64.3	318.2

^a Volumes outside National Forest are based on trees measured on sample plots. Total tree volume is for trees 3 inches and larger at root collar and includes volume of wood and bark in segments at least 1 foot long to a small-end diameter of 1.5 inches. Main-stem volume is for trees 5.0 inches and larger d. b. h. and includes volume from a 1-foot stump to a top diameter of 4 inches outside bark. In pinyon-juniper type, total tree volume is based on measurements of segments; in western juniper type, total tree volume is based on ratios of volume in the main stem to total tree volume on a subsample of trees. Volumes in National Forests were developed by applying average volume per acre by type from plots outside National Forests to the area by type in National Forests.

Volumes Per Acre

Total tree volume averages 322 cubic feet per acre in western juniper stands, and 580 cubic feet in pinyon-juniper stands. Main-stem volume averages 178 cubic feet per acre (about 2 cords) in western juniper and only 91 cubic feet (about 1 cord) in pinyon-juniper stands. In terms of total woody biomass, pinyon-juniper stands appear to be more productive. In terms of potential for harvestable wood for salable products such as fuelwood, timbers, and saw logs, western juniper stands are more productive.

Volume by Species Outside National Forests

Singleleaf pinyon volume totals 258.0 million cubic feet, 50 percent of total tree volume in western juniper and pinyon-juniper types outside National Forests. Western juniper volume totals 222.5 million cubic feet, about 43 percent. In terms of main-stem volume, the ranking is reversed, with western juniper accounting for 70 percent and singleleaf pinyon for only 23 percent. Singleleaf pinyon grows in denser stands than western juniper, but pinyon trees are shorter and less well-formed than western juniper. Of the eight tree species found in western juniper and pinyon-juniper stands, three—Utah juniper, California juniper, and interior live oak—are too poorly formed to have measurable volume in main-stem sections (table 8).

Table 8—Total tree and main-stem volume by species in western juniper and pinyon-juniper woodland outside National Forests and parks and other reserved areas, California, 1985

Species	Volume	
	Total tree	Main stem
	<i>Million cubic feet</i>	
Western juniper	222.5	122.1
Utah juniper	17.5	0
California juniper	9.3	0
Singleleaf pinyon	258.0	40.5
Jeffrey pine	6.0	5.7
Ponderosa pine	4.1	3.9
Oregon white oak	2.0	1.3
Interior live oak	1.2	0
Total	520.6	173.5

Volume by Tree Size

Total tree volume indicates the amount of woody biomass usable as fuel or fiber or, conversely, the amount of material that must be dealt with in vegetation management. Main-stem volume is a measure of the amount of wood that might be useful for products such as lumber, fencing material, and specialty items. Knowing the distribution of total tree volume and main-stem volume by tree size can be useful in determining methods and costs of extracting the resource, assessing the range of product potential, and planning land management activities.

Outside National Forests, about 60 percent of the total tree volume in all species is in trees with less than 30 cubic feet. In western juniper, 86 percent of total tree volume was concentrated in trees with less than 30 cubic feet; in singleleaf pinyon, 43 percent of total tree volume was in trees with less than 30 cubic feet, and 50 percent was in trees with more than 50 cubic feet (table 9). The unusually high percentage in the larger volume class in singleleaf pinyon reflects the occurrence of scattered large, well-formed trees growing in moist canyons and on north-facing slopes, and the scarcity of well-formed trees among the large number of smaller specimens. As shown in table 10, total main-stem volume in singleleaf pinyon is less than one-third of that in western juniper (40.5 million cubic feet vs. 122.1 million), yet the volume of singleleaf pinyon trees 29 inches d.b.h. and larger is greater than that of western juniper trees of that size (16.8 million cubic feet vs. 12.2 million).

Table 9—Total tree volume in western juniper and pinyon-juniper woodland outside National Forests and parks and other reserved areas, by species and volume-per-tree class, California, 1985

Species	Volume by volume-per-tree class					Total
	Less than 10 ft ³	10.0-29.9 ft ³	30.0-29.9 ft	40.0-49.9 ft ³	50.0+ ft ³	
<i>Million cubic feet</i>						
Western juniper	88.2	101.9	16.7	7.0	8.7	222.5
Utah juniper	4.8	0	0	0	12.7	17.5
California juniper	1.3	4.5	0	3.5	0	9.3
Singleleaf pinyon	43.6	63.4	7.6	15.0	128.4	258.0
Jeffrey pine		2.5	0	0	3.5	6.0
Ponderosa pine	0	0	0	0	4.1	4.1
Oregon white oak	2.0	0	0	0	0	2.0
interior live oak	1.2	0	0	0	0	1.2
Total	141.1	172.3	24.3	25.5	157.4	520.6

^a Less than 50,000 cubic feet.

Table 1—Main-stem volume in western juniper and singleleaf pinyon trees in western juniper and pinyon-juniper woodland outside National Forests and parks and other reserved areas, by diameter class, California, 1985^a

Diameter class	Main-stem volume		
	Western juniper	Singleleaf pinyon	Total
Inches	<i>..... Million cubic feet - - - - -</i>		
5.0-6.9	7.0	0.7	7.7
7.0-8.9	6.9	2.8	9.7
9.0-10.9	13.6	3.7	17.3
11.0-12.9	14.8	3.1	17.9
13.0-14.9	9.2	3.4	12.6
15.0-16.9	10.7	4.3	15.0
17.0-18.9	15.0	.7	15.7
19.0-20.9	11.5	0	11.5
21.0-28.9	21.2	5.0	26.2
29.0+	12.2	16.8	29.0
Total	122.1	40.5	162.6

^a Western juniper and singleleaf pinyon were the only species of juniper and pinyon in the inventory to have measurable main-stem volume.

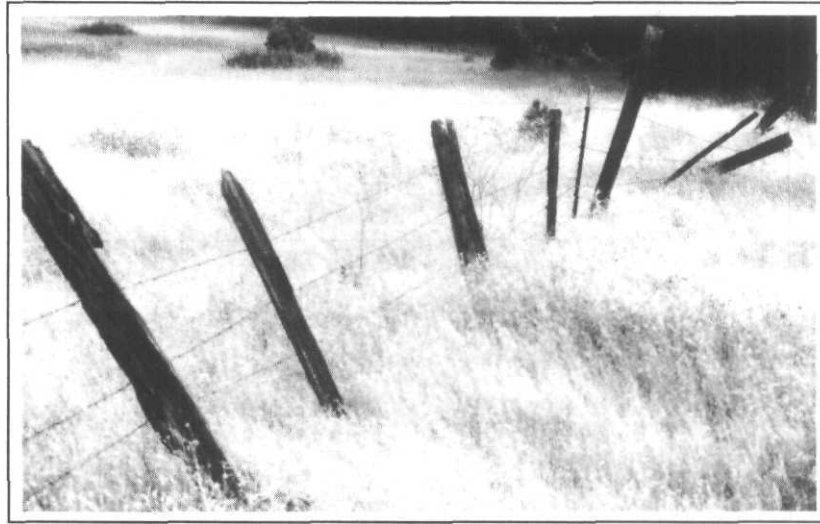


Figure 9—Fencing is one of the major investment needs in western rangelands where millions of juniper posts could be used.

Juniper Fenceposts

Fences are important to sound range management for controlling forage use by livestock, protecting fragile sites, keeping livestock away from highways and other hazards, and protecting property. Fencing was one of 18 major range improvement investment needs summarized in “The Nation’s Range Resources—A Forest-Range Environmental Study” (USDA Forest Service 1972) (fig. 9).

The durability of juniper fenceposts is well known in the Western rangelands, where it has been said that “a juniper post will outlast two post holes.” All species of juniper have very durable heartwood, and juniper posts can be expected to last 30 to 50 years (Barger and Ffolliott 1972, Miller 1986). Pinyon has occasionally been used for fenceposts, but it usually rots out in 4 to 6 years (Barger and Ffolliott 1972). Although steel and treated pine and Douglas-fir fenceposts are commonly used, juniper posts are still used in many areas, often in combination with steel posts or treated wooden posts (fig. 10). For many ranchers, home-grown juniper posts are less expensive than steel, treated pine, or treated Douglas-fir posts; the expected service life of juniper posts is adequate to keep maintenance costs acceptable.

Fencepost Standards

In the woodland inventory, for each juniper tree tallied, crews estimated the number of potential fenceposts. Fencepost standards used in the inventory were based on post specifications used by western juniper fencepost dealers in central and southern Oregon. These post standards are similar to those for fenceposts made of Utah juniper, one-seed juniper (*Juniperus monosperma* (Engelm.) Sarg.), and alligator juniper (*J. deppeana* Steud.) in Arizona (Barger and Ffolliott 1972) with this exception: In Arizona, most juniper posts are cut from small trees and are unsplit (a small number of split posts are made from large alligator junipers). Western juniper trees in California are often large and straight enough to be split. Split posts are more durable than unsplit (round) posts because they expose less sapwood to the soil; split posts also are less likely to loosen in the soil as round posts do when the outer ring of sapwood rots (despite this problem, many ranchers use round unpeeled juniper posts [fig 11; also see fig. 10]).

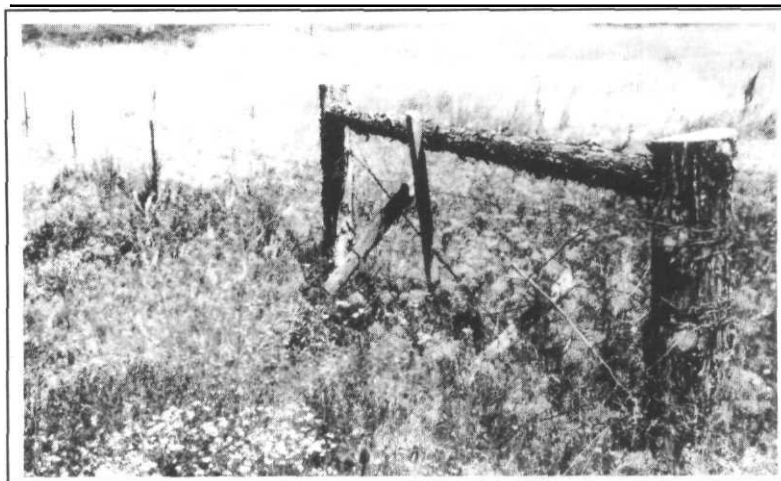


Figure 10—Stout juniper posts are often used for corners and braces in fences made with steel line posts.

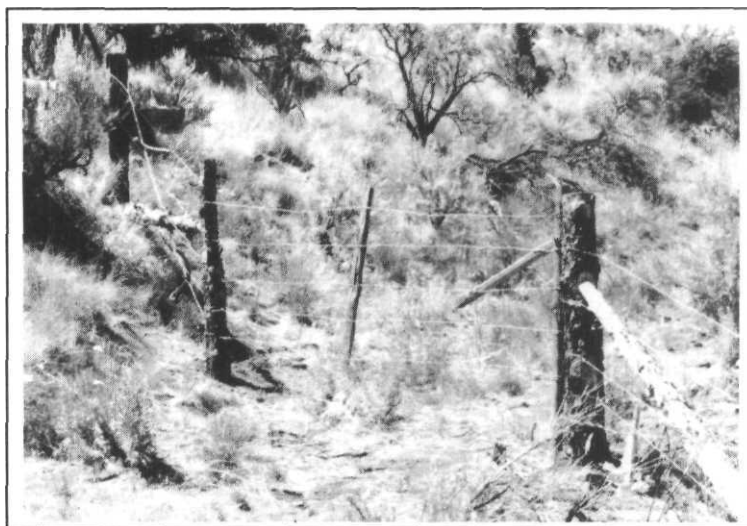


Figure 11—Although peeled and split posts last longer, unpeeled and unsplit juniper posts are frequently used in northeastern California.

I used the following fencepost standards in this study:

- Post length-8 feet; section must be straight.
- Minimum cross-sectional area at small end of a post—12 square inches (boles 4 to 5 inches in diameter at small end will make round posts, and boles 6 inches and larger at small end will make split or sawn posts, grain spirality and knot-size permitting).
- Minimum width of outer arc of split posts 4 inches.

- Grain spirality—maximum allowable divergence of grain from the vertical for split posts is one-fourth bole circumference in 8 feet; if more than one-fourth bole circumference, posts are sawable or round.
- Knot size—maximum allowed for split post is one-fourth bole circumference; larger knots reduce the number of split posts or make entire bole into a round post.
- Soundness—section must be without decay or holes.

Table 11 shows diameters and corresponding numbers and dimensions of juniper posts.

**Potential Fenceposts—
More Than 140 Million**

Outside National Forests and Parks and other reserved areas, the total number of potential fenceposts in juniper trees is about **81** million. More than 80 percent of the estimated fenceposts are in splittable sections, and 2 percent are in sections that, because of excessive grain spirality, could only be sawn. Round posts amount to **13** percent of western juniper posts and 100 percent of California juniper and Utah juniper posts (see table 12).

Table 11—Size specifications for estimating number of fenceposts in juniper trees in California^a

Small-end diameter	Outer arc length	Wedge length (radius)	Fenceposts
----- Inches -----			Number
4	<i>b</i>	<i>b</i>	1
5	<i>b</i>	<i>b</i>	1
6	9.4	3.0 ^c	2
7	7.3	3.5	3
8	6.3	4.0	4
9	5.7	4.5	5
10	5.2	5.0	6
11	4.3	5.5	8
12	4.2	6.0	9
13	4.1	6.5	10
14	4.4	7.0	10
15	4.3	7.5	11
16	4.6	8.0	11
17	4.4	8.5	12
18	4.3	9.0	13

^a Bole sections with small-end diameter of 4-18 inches are included, although many juniper trees with diameters greater than 15 inches are too rough or rotten for fenceposts.

^b Round posts.

^c Half-round posts.

Table 12—Number of juniper fenceposts In western juniper and pinyon-juniper woodland outside National Forests and parks and other reserved areas, by species and cross-sectional shape, California, 1985

Species	Fenceposts			Total
	Round	Half-round or wedge		
		Splittable	Sawable only	
<i>Thousand posts</i>				
Western juniper	10,392	66,595	1,474	78,461
California juniper	2,177	0	0	2,177
Utah juniper	628	0	0	628
Total	13,197	66,595	1,474	81,266

Table 13—Number of juniper fenceposts in western juniper and pinyon-juniper woodland outside parks and other reserved areas, by species and ownership group, California, 1985

Species	Fenceposts			Total
	National Forest	Other public	Private	
<i>Thousand posts</i>				
Western juniper	59,128	49,352	29,109	137,589
California juniper	0	1,306	871	2,177
Utah juniper	2,968	440	188	3,596
Total	62,096	51,098	30,168	143,362

Based on the average number of juniper fenceposts per acre outside National Forests, the number in National Forests is about 62 million. The total number of fenceposts, including the sample-based estimate for lands outside National Forests and approximated number in National Forests, is 143 million. Most are western juniper (table 13).

A**B**

Figure 12—"Rock jacks" and "cribs" are used where the soil is too rocky for post holes: (A) "Rock jack" made of six split juniper posts. (B) "Crib" made of treated pine posts and boards. Juniper posts are often used in "cribs."

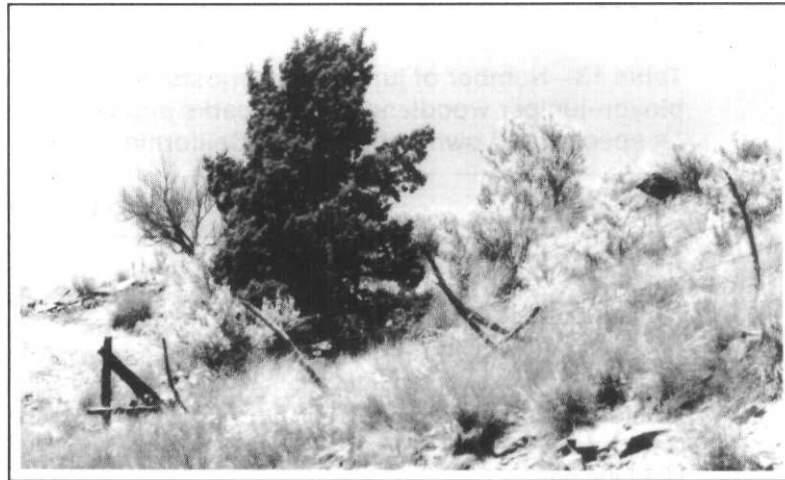


Figure 13—In this fence, juniper limbs are interspersed between steel posts, "rock jacks," and "figure 4's" (center of picture). "Figure 4's" are usually made of three posts or of two posts and a board. This "figure 4" is made of three juniper limbs.

At the conventional spacing of one line post every 16.5 feet (1 rod) with additional posts for braces, "rock jacks," "cribs," and "figure 4's" (figs. 12 and 13), the 143.4 million posts in California's pinyon and juniper woodlands are sufficient to build about 400,000 miles of fence. These fenceposts include only those meeting the standard of posts sold commercially (they actually exceed the standard for line posts, which are usually 6 or 7 feet long rather than 8). In some areas, substandard posts consisting of small tree trunks, limbs, or shrub species are interspersed between steel or commercial-quality wooden posts, "rock jacks," and "figure 4's" (fig. 13). This practice can greatly increase the miles of fence that could be built with the juniper fenceposts in the western juniper and pinyon-juniper woodlands of California.

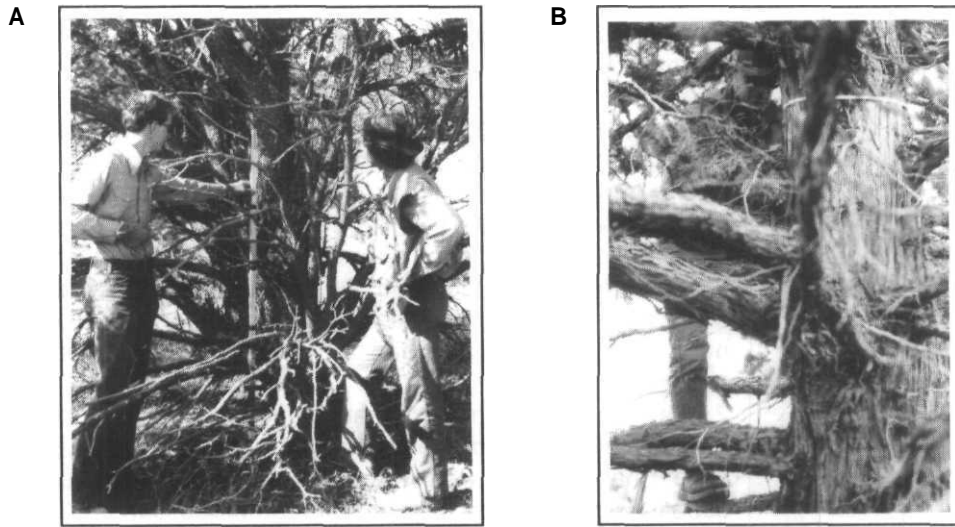


Figure 14—The limbiness and poor form of many juniper trees make fencepost cutting laborious and expensive: (A) Utah juniper. (B) Western juniper.

In **1988**, the retail price of farm steel T-posts ranged from about **\$1.80** each for light-weight posts to **\$3.00** each for heavyweight. Pressure-treated wooden posts 2.5 to 4 inches in diameter are similarly priced; larger posts cost up to \$5.00 each. The value of the **143.4** million potential juniper posts, in terms of the cost of steel or pressure-treated wooden posts they could replace, is about **\$360** million (based on an average value of \$2.50 per post).

Cutting juniper fenceposts is a rather slow and laborious process, because of the limbiness and poor form of many juniper trees (fig. 14). In Arizona, juniper post cutters produced **4 to 7** posts per hour (Barger and Ffolliott **1972**). At that rate and at **1988** minimum wages (**\$3.35** per hour), the cost of cutting juniper posts would amount to **20 to 33** percent of the **1988** retail price of posts and **47 to 82** percent of the wholesale price. Western juniper trees in California are generally straighter than juniper trees in Arizona and probably can be cut into posts faster. Still, the margin for profit is narrow and unlikely to attract many post cutters. An increase in the price of steel and pressure-treated wooden posts, however, could make commercial juniper post operations attractive. (Fiberglass posts have recently entered the market, but have been used mostly for electric fences in farming areas; future development of fiberglass posts could affect the prospects for increased use of juniper posts.)

Fenceposts have provided some revenue to help offset costs of clearing juniper in rangeland improvement projects (Bedell **1984**) and remain a potential resource that may, along with fuelwood and other wood and biomass products, become more important in the future.

Conclusions

This paper has outlined and detailed some of the resources in western juniper and pinyon-juniper woodlands in California. The major findings are as follows:

1. Western juniper and pinyon-juniper woodlands are predominantly (81 percent) in government ownership, and most of this is in National Forests and land managed by the Bureau of Land Management. By far the greatest use of these woodlands has been for livestock grazing with tree clearing to improve forage production the primary management activity in many areas. Wildlife management considerations affect activities in some areas. On the 50,000 acres within parks and other reserved areas, passive preservation of the western juniper and pinyon-juniper woodlands is a management goal, though some clearing by natural-caused fires has occurred.
2. Western juniper woodland seems to offer more options for wood or biomass products as well as forage production than does pinyon-juniper woodland. Western juniper has less total woody material to contend with, but higher potential yield in usable wood products and better forage production in cleared as well as uncleared areas.
3. The spread of western juniper and pinyon-juniper types seems to have equaled or surpassed the area cleared since 1945. The spread of these types, although considered detrimental to the condition of rangeland, is not considered bad by everyone. Many species of wildlife thrive in these woodlands, and juniper and pinyon trees are pleasing to look at. They impart a unique character to the canyons and plateaus of the arid interior.
4. The rate of spread of juniper and pinyon appears to be decreasing, as indicated by the predominance of trees in the 50-to-100-year class and the scarcity in most areas of trees less than 50 years old. Whether this is a result of range management practices, weather, pathogens, lack of new places suitable for juniper and pinyon trees, or other factors is unknown. Some changes in management—the emphasis has been on eliminating juniper and pinyon trees—may be in order in the future if the area in these types becomes static or declines.
5. Total woody biomass in western juniper and pinyon-juniper woodlands is a sizable potential resource that can be used for many purposes besides fuelwood and fenceposts, the current major uses of pinyon and juniper wood. The economics of pinyon-juniper biomass harvesting do not favor its use now, but that could change.
6. The inventory reveals a vast fencepost resource, and it is in an area where old fences need repairing and new fences need to be built. Relative prices of other kinds of posts and the costs of converting limby, knotty juniper trees into usable posts discourage using this resource. A slight change in the price of steel and pressure-treated wooden posts could make juniper post cutting more attractive. Locally cut juniper posts are used by many ranchers, and this type of use is expected to continue. In some areas where juniper and pinyon-juniper types are being cleared in rangeland improvement projects, post production could help offset the cost of conversion.

Terminology

Basal area—The cross-sectional area of a tree stem. In this study, basal area was determined at breast height in western juniper stands and at root collar (usually at ground level) in pinyon-juniper stands.

Breast height—See “Diameter class.”

Bureau of Land Management lands—Federal lands administered by the U.S. Department of the Interior, Bureau of Land Management.

Chaparral—Areas covered with heavily branched dwarf trees or shrubs, usually evergreen, the crown canopy of which at maturity usually covers more than 50 percent of the ground. The principal genera are *Adenostoma*, *Arctostaphylos*, *Ceanothus*, *Cercocarpus*, *Garrya*, and *Quercus*.

Diameter class—A classification of trees based on diameter outside the bark. In western juniper stands, all tree diameters were measured at breast height, 4-1/2 feet above the ground. In pinyon-juniper stands, all tree diameters were measured at root collar (usually at ground level); trees with main stems at least 4-1/2 feet high were also measured at breast height.

Forest land—Land at least 10 percent covered by crowns of live trees, or formerly having such cover and not currently developed for nonforest use. Land from which juniper or pinyon trees have been cleared is classified as nonforest with or without additional evidence of nonforest development. The minimum area for classifying forest land is 1 acre.

Forest land, reserved—Forest land withdrawn from use for the production of most commodities (such as lumber, fence posts, and fuel wood). Included are National Forest wilderness, parks, and other reservations.

National Forest land—Federal lands that have been designated by Executive order or statute as National Forest or purchase units, and other lands under the administration of the Forest Service including experimental areas and Bankhead-Jones Title III lands.

Native American lands—Tribal and allotted lands held in trust by the Federal Government.

Oak woodland—Woodland dominated by oak trees. In this report references to oak woodland are sometimes preceded by the common name of the oak species; for example, Oregon white oak woodland (woodland dominated by *Quercus garryana*) or blue oak woodland (woodland dominated by *Q. douglasii*).

Other public lands—Lands administered by public agencies other than the USDA Forest Service.

Pinyon-juniper woodland—Woodland area dominated by one or more of these species: *Pinus edulis*, *P. munophylla*, *P. quadrifolia*, *Juniperus californica*, and *J. osteosperma*. Woodland area dominated by *J. occidentalis* is classified as western juniper woodland.

Quadratic mean diameter—The diameter of the tree of average basal area.

State lands—Lands owned or administered by State agencies.

Timberland—Forest land capable of continuously producing 20 cubic feet or more per acre per year of industrial wood (in straight logs at least 8 feet long in hardwoods and 12 feet long in softwoods).

Western juniper woodland—Woodland area dominated by *Juniperus occidentalis*.

Woodland—Forest land incapable of continuously producing 20 cubic feet per acre per year of industrial wood because of climate or soil conditions.

Metric Equivalents

1,000 acres = 404.7 hectares

1,000 cubic feet = 28.3 cubic meters

1 cubic foot per acre = 0.07 cubic meter per hectare

1 foot = 0.3048 meter

1 inch = 2.54 centimeters

1 mile = 1.609 kilometers

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The results of a statewide inventory of western juniper and pinyon-juniper woodlands are presented. Included are statistics on area of woodland by type and ownership; area of rangeland with scattered juniper and pinyon trees; wood volume by ownership, species, and tree size; juniper fenceposts; tree and stand age distribution; stand characteristics, including overstory and understory; and a discussion of resource potential and changes in western juniper and pinyon-juniper woodland since 1945.

Keywords: Juniper, pinyon, fenceposts, forest inventory, California.

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