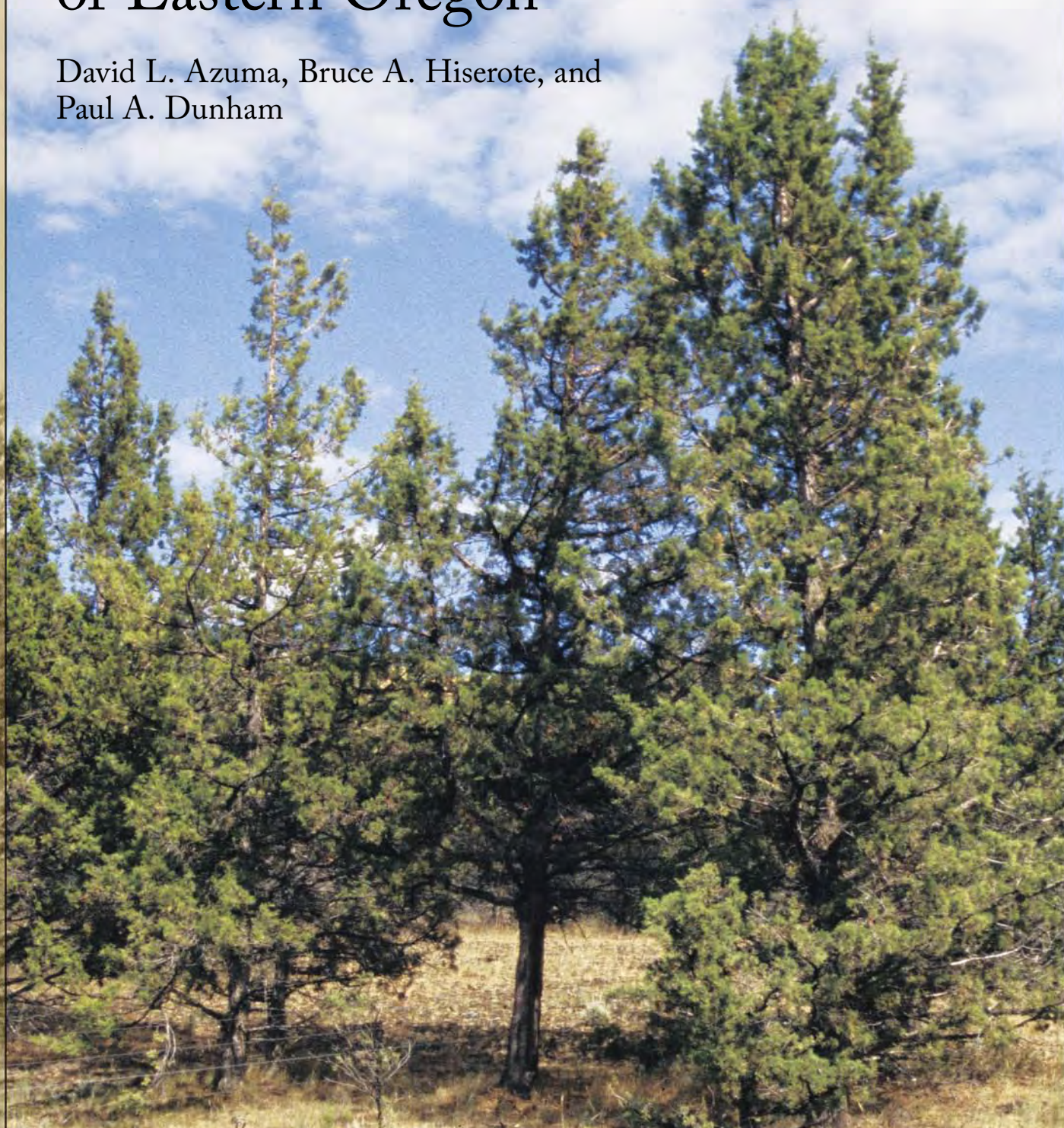


The Western Juniper Resource of Eastern Oregon

David L. Azuma, Bruce A. Hiserote, and
Paul A. Dunham



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Authors

David L. Azuma is a research forester, **Bruce A. Hiserote** is an information technology specialist, and **Paul A. Dunham** is a forester, Forestry Sciences Laboratory, P.O. Box 3890, Portland, OR 97208-3890.

Abstract

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This report summarizes resource statistics for eastern Oregon's juniper forests, which are in Baker, Crook, Deschutes, Gilliam, Grant, Harney, Jefferson, Klamath, Lake, Malheur, Morrow, Sherman, Umatilla, Union, Wallowa, Wasco, and Wheeler Counties. We sampled all ownerships outside of the National Forest System; we report the statistics on juniper forest on national forest lands by using data from the national forest, Pacific Northwest Region inventory. Statistical tables summarize the area covered by juniper trees and juniper forest, wood volume, and numbers of trees, by ownership and juniper type. We found juniper on an estimated 6.5 million acres, a little more than half that was considered forest land. Evidence suggests that amount of forest land will continue to increase.

Keywords: Forest inventory, western juniper, resource statistics, eastern Oregon.

Summary

Western juniper exists across a large expanse of eastern Oregon, over 6 million acres. It generally grows in multiaged stands with crown cover of less than 50 percent. We classify juniper stands as forest or savanna based on stocking of 5 percent or greater as being forest. The majority of the juniper forest is split almost evenly between the Bureau of Land Management and other private owners. The volume is estimated to be 766 million cubic feet, which is a little less than half that of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) outside of national forests.

The estimated acres of juniper forest and savanna in Oregon have increased dramatically since the 1930s from about 1.5 million acres to around 6.5 million acres. Area classified as juniper forest has increased from 420,000 acres to over 3 million. Over 1 million acres of area classed as juniper savanna have more than 25 trees per acre. Over one-third of the acres classed as savanna had seedlings. All indications are that the area of juniper forest will continue to increase.

Preface

Forest Inventory and Analysis (FIA) is a nationwide program of the USDA Forest Service authorized by the Forest and Rangeland Renewable Resources Research Act of 1978. Work units, located at Forest Service research and experiment stations, conduct forest resource inventories throughout the 50 States. The FIA Program of the Pacific Northwest Research Station in Portland, Oregon, is responsible for forest inventories in Alaska, California, Oregon, Washington, Hawaii, and the Pacific Islands.

Contents

- 1 **Introduction**
- 3 **Inventory Procedures**
- 4 **Reliability of Inventory Data**
- 5 **Juniper Forest and Savanna**
- 6 **Juniper Area and Ownership**
- 9 **Changes From the 1988 Inventory**
- 9 **Juniper Volume**
- 12 **Growth, Mortality, and Removals**
- 13 **Discussion**
- 15 **Metric Equivalentents**
- 16 **Names of Trees**
- 16 **Literature Cited**

Introduction

The Forest Inventory and Analysis (FIA) Program of the Pacific Northwest Research Station conducted a multiresource inventory in eastern Oregon's juniper forests in 1999. This inventory included all lands except those administered by the USDA Forest Service. This report summarizes the resource statistics for eastern Oregon's juniper forests. Some statistical tables include inventory data provided by the USDA Forest Service for juniper forests on their lands. Other resources sampled but not included in this report include understory vegetation, crown cover, coarse woody debris, and snags. These data will lead to further analysis of the status of eastern Oregon's juniper forests.

The FIA unit has periodically reported statistics for eastern Oregon since the 1930s, e.g., Cowlin (1942), Bolsinger and Berger (1975), Farrenkopf (1982), Gedney et al. (1989), and Azuma et al. (2002). Gedney et al. (1999) reported on the juniper forests inventoried in 1988. This report summarizes statistics from over 400 plots taken over the range of juniper conditions across eastern Oregon.

Western juniper¹ grows on xeric lands across eastern Oregon with the majority of stands growing where precipitation is between 10 and 20 inches per year and at elevations between 3,000 and 5,000 (Gedney et al. 1999) (fig. 1). Crown closure in juniper stands ranges from 60 percent to very sparse with only one to a few trees per acre. Many juniper stands contain trees that range in age from 1 to over 100 years. Juniper successfully competes against other native plants like sagebrush (*Artemisia* spp. Nutt.) and grasses. Sometimes sagebrush serves as a shrub, with juniper establishing in the protected areas directly beneath (Eddleman 1986). As juniper stands age, they tend to exclude other native species through moisture competition (Evans and Young 1987).

The expansion of western juniper over the last 120 years has been well documented (Eddleman 1986, Gedney et al. 1999, Miller et al. 2000, Young and Evans 1984). Overgrazing by domestic livestock, fire suppression, and climatic shifts (Burkhardt and Tisdale 1976, Knapp and Soule 1998, Miller and Rose 1995, Young and Evans 1984) are believed to be the causes of juniper's phenomenal expansion. The hypothesis is that overgrazing has reduced the amount of fuel available to carry fire, and fire suppression has reduced the occurrence of fires that would have killed smaller juniper in sparsely populated stands. This coupled with a warmer, wetter climate conducive to seedling establishment has created favorable conditions for juniper to establish and expand its range. In 1936, Cowlin et al. (1942) estimated

¹See "Names of Trees" for nomenclature.

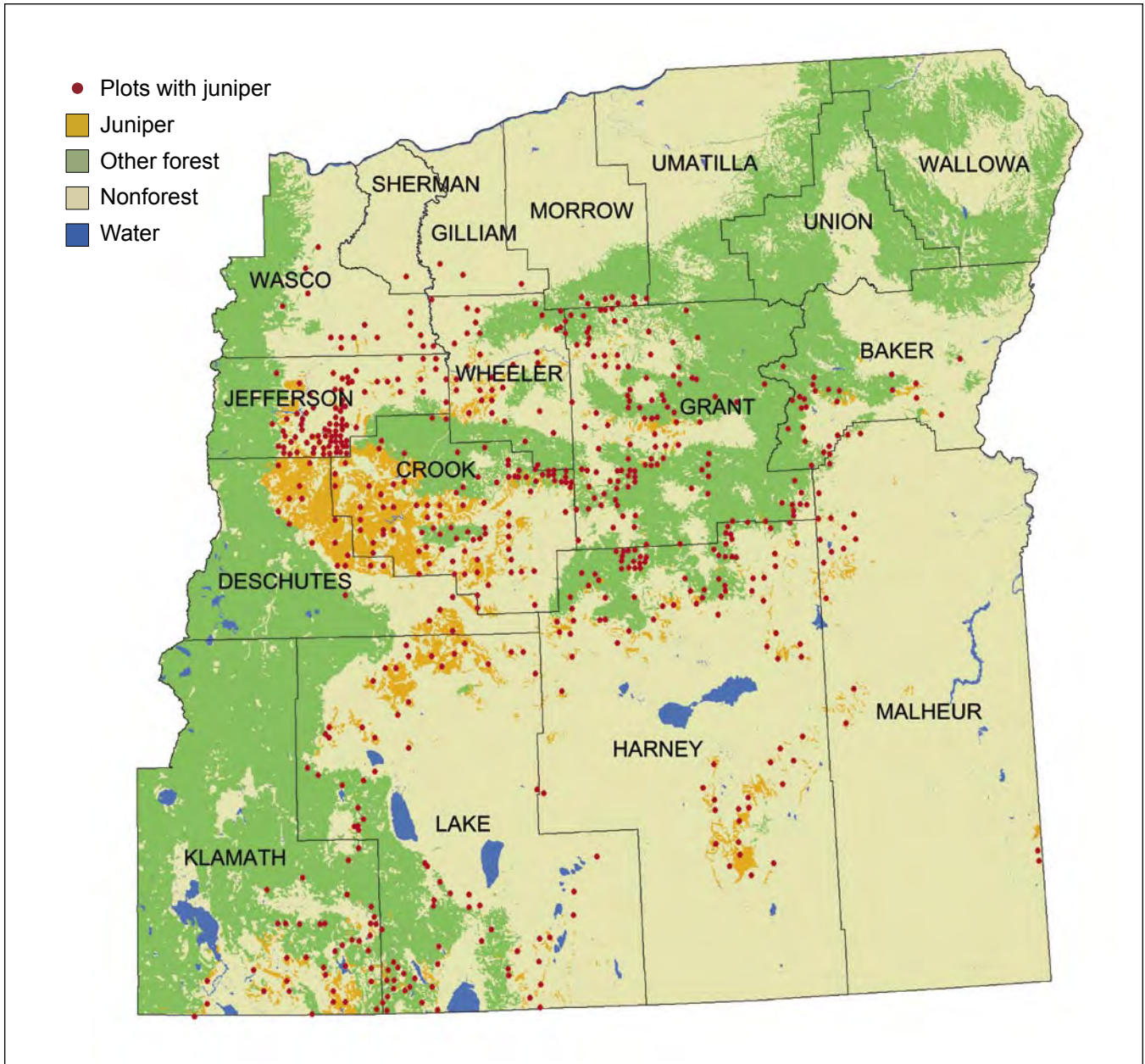


Figure 1—Plots with western juniper in eastern Oregon with 1936 vegetation type map.

the area of juniper forest in eastern Oregon to be around 420,000 acres. In 1999, Gedney et al. estimated the acreage at about 2.2 million acres by using aerial photography.

Western juniper was inventoried in 1999 as part of the eastern Oregon inventory conducted by the FIA Program of the Pacific Northwest Research Station. This inventory was initiated to supplement the timberland inventory conducted in 1998 and as a follow-on to the 1988 juniper inventory. Many of the area statistics

calculated in the juniper 1988 inventory were based on the cover that could be estimated from 1:40,000-scale aerial photos. In some circumstances, there were enough smaller juniper trees on a plot to qualify it as juniper forest; however, the smaller trees would not have been visible on the aerial photo, and would have been missed in the 1988 inventory. The 1999 inventory established ground plots on areas that were expected to have up to 9 percent cover as well as areas where juniper cover had been previously evaluated as greater than this threshold.

The expansion of juniper forest over a large area of eastern Oregon has had a pronounced effect on the landscape. Several researchers have reported that the increasingly abundant juniper will outcompete other native vegetation, making the land less productive for grazing (Gholz 1980). Others have hypothesized that juniper uses more water than other range vegetation, thereby reducing flow (Miller et al. 1987, Miller and Shultz 1987). Juniper can also reduce through-fall precipitation by interception and subsequent evaporation and sublimation reducing the amount of moisture actually reaching the soil (Young and Evans 1984). Still others have looked at the amount of perch sites available for raptors in relation to the prey species. A study in Oklahoma evaluating decreases in the population of avian species dependent upon an open sage/grassland habitat (Coppedge et al. 2004) offers parallels for the juniper encroachment occurring in eastern Oregon.

The vast expansion of juniper has led landowners to attempt a variety of control measures, including cutting, chaining, and burning. All are relatively expensive, and most involve subsequent treatments (Evans and Young 1987).

Inventory Procedures

The 1999 inventory of juniper in eastern Oregon sampled all lands with juniper present outside national forests. It also included a sample of plots where juniper was in proximity as judged from aerial photos, but not actually on the plot. The sampling scheme used the photointerpreted categories in the 1988 inventory as an initial stratification scheme. The 1988 photointerpretation classified sample points as to the percentage of cover but excluded some areas that were believed to have no juniper. In 1998, every secondary sample location that was excluded in the 1988 photo work was evaluated by aerial reconnaissance. Using a global position system receiver to locate the point on the ground, an observer estimated the juniper cover and proximity to offsite junipers for these plots. These plots were subsequently included in the set of plots to be considered for ground sampling.

The juniper land of eastern Oregon was inventoried by using double sampling for stratification (Cochran 1977). The sample of ground plots was determined by choosing a random sample from the possible ground locations within categories

of juniper cover as determined from aerial reconnaissance or photointerpretation. Plots with juniper cover of at least 10 percent were sampled at a rate of about 50 percent, plots with estimated cover between 1 and 9 percent at 20 percent, and plots with no estimated juniper cover at 5 percent.

Sample plots were located on a permanent systematic grid producing an even geographic distribution of both the field and photointerpreted locations. Ground plots were installed by using the FIA national program's 4-point, mapped design. On the 57 co-located plots that had been previously established in the 1988 inventory as a 5-point design, field crews assessed all previously measured trees for mortality, harvest, and growth before installing a new national-design (4-point) plot centered on the same location.

The new plot design consisted of a cluster of four 24-foot-radius subplots, totaling one-sixth of an acre, each with an annular ring extending to 59 feet covering about 2.1 acres in total (USDA 1999). All juniper trees regardless of size were sampled in the 24-foot-radius plot. Because larger trees tend to be rare in juniper forests, trees larger than 20 inches were sampled on the 59-foot-radius plot. The plot design also accounted for different land classes within the plot, known as condition classes. Condition classes were mapped on the plot delineating different situations that could occur such as, roads, pastures, and other forest and nonforest conditions. When multiple forested conditions existed on a plot, the data for each condition were processed separately.

The information collected on the plot included tree attributes (diameter, height, species, crown ratio, crown diameters, and terminal and lateral leader growth category); size and abundance of down wood; understory vegetation species, cover, and height; and various stand characteristics (e.g., age, size, and forest type). Individual tree crown area was computed as an ellipse with the perpendicular crown diameter measurements defining the axes. Woody biomass for individual trees was computed as total aboveground biomass, including bole, bark, and branches.

The area and volume statistics reported for national forests are based on the data collected by the USDA Forest Service, Pacific Northwest Region Continuous Vegetation Survey Program (Max et al. 1996)

Reliability of Inventory Data

Inventories are designed to provide sampling errors consistent with national standards set by the USDA Forest Service. The target sampling errors for area of low-productivity forest land such as juniper is 10 percent per million acres.

The sample design for this inventory provides the highest precision when estimates are aggregated for all eastern Oregon. As the sample is divided into smaller

units, the confidence intervals increase as a proportion of the estimate. Standard errors for marginal totals are included for most of the tables. Confidence intervals are quantitative expressions of the variability inherent in the sampling and estimation procedures. The tabulation below indicates, for instance, a 68-percent (one standard error) chance that the true forest or savanna area (estimated at 3,339,000 acres) is within the range of (3,173,000 and 3,505,000).

Area and volume estimates and standard errors for juniper forest and savanna, by owner class, are displayed below:

Owner	Area		Volume	
	Forest	Savanna	Forest	Savanna
	<i>Thousand acres</i>		<i>Million cubic feet</i>	
Other public	472 ±22	174 ±50	96 ±9	17 ±3
BLM	1,534 ±156	1,196 ±168	328 ±42	21 ±5
Other private	1,556 ±154	1,869 ±319	247 ±33	35 ±10
All owners	3,339 ±152	3,227 ±340	671 ±45	73 ±12

Confidence intervals vary with the size of the estimate and the amount of variance associated with the estimate. As estimates get small, the standard errors will come close to 100 percent of the estimate, although a small estimate means that the attribute existed (i.e., is nonzero), we cannot be confident in the actual number.

Juniper Forest and Savanna

The definition of juniper forest for the 1988 inventory was 10 percent or greater crown cover on the plot interpreted from aerial photography. The crown cover definition was a surrogate for the area occupancy of juniper or other trees. Because of their relative size, the seedlings and saplings contribute almost nothing to a definition that considers only crown cover. The persistence of juniper seedlings and saplings suggests that these junipers should be accounted for when defining forest land. We used stocking of 5 percent or greater (meaning 5 percent of full stocking), which includes the contribution of the seedlings and saplings, to define juniper forest. Juniper tends to grow on less productive sites than ponderosa pine, where a stocking level of 10 percent or greater defines forest land. As the capability of the land to support trees decreases, the stocking that will occupy the resources of the site decreases. Gedney et al. (1999) hypothesized that lateral root extension of as few as nine mature juniper trees per acre could fully occupy an acre. The Forest Service (USDA 1999) uses a definition of 40 trees per acre to define forest land for pinyon juniper lands to intermountain West. Applying this definition yields almost the same number of acres as the 5-percent-stocking rule.

We defined juniper savanna as land with juniper trees growing on it but less than 5 percent stocking. Despite their low current stocking, such lands may well transition to juniper forest (Gedney et al. 1999). At least some of the savanna lands will continue to increase in canopy density, as evidenced by the proportion of the estimated total number of trees that are seedlings: 68 percent for savanna and 53 percent for juniper forest (table 1). We estimated 695,000 acres of juniper savanna that had more than 25 seedlings per acre. The numbers of seedlings found suggests that these lands are still increasing in tree density.

Juniper forest is characterized by open-grown sparsely stocked stands. About 30 percent of juniper forest has greater than 50 percent crown cover. Approximately 48 percent of the juniper forest acres have crown cover between 10 and 40 percent (table 2). An interesting point is the occurrence of 8 percent of the juniper forest acres that have less than 10 percent crown cover but still have more than 25 trees per acre. This suggests that under steady-state conditions, over 50 percent of the juniper forest land could have 10 to 40 percent cover in the relatively near future. About 15 percent or 460,000 acres of the juniper forest land has more than 75 trees per acre but less than 20 percent crown cover. One might expect that on these lands, as the trees grow in size, cover would continue to increase to somewhere between 20 and 40 percent cover.

Juniper Area and Ownership

With the exception of the ponderosa pine type, which covers 4.9 million acres (Campbell et al. 2003), juniper forests occupy more area than any other forest type in eastern Oregon, over 3.5 million acres (table 3). If the crown density of juniper trees continues to increase on these savanna lands, juniper forests may become the forest type with the most acres in eastern Oregon. The average percentage of juniper area, forest or savanna, across the counties with juniper is 20 percent. Crook County has the greatest percentage of its area in juniper with over 58 percent, followed closely by Wheeler and Jefferson Counties with 46 and 34 percent, respectively.

Most juniper forest and savanna lands (52 percent) are privately owned. The BLM manages about 43 percent (table 3). The private ownership category contains individuals, corporate owners, and native American tribes. When considering only lands classified as forest, the percentages of ownership are very close between the private sector and the BLM, 47 and 46 percent, respectively. The remaining proportion, totaling about 7 percent, is National Forest System and other public lands.

Table 1—Estimated number of western juniper trees by forest type class, owner, and diameter class for eastern Oregon, 1999

Owner	Diameter class (inches)													All classes	Standard error
	Seedlings	1.0–2.9	3.0–4.9	5.0–6.9	7.0–8.9	9.0–10.9	11.0–12.9	13.0–14.9	15.0–16.9	17.0–18.9	19.0–20.9	21.0–28.9	29+		
<i>Thousand trees</i>															
Juniper forest:															
Bureau of Land Management	79,282	16,718	12,288	16,825	14,659	13,001	5,815	3,497	3,023	1,772	1,363	1,521	635	170,398	(20,600)
Other public	4,876	4,619	2,601	2,109	1,447	861	302	96	112	112	15	47	48	17,247	(7,709)
Private	131,755	19,121	16,031	17,266	11,829	9,085	4,010	3,799	1,780	1,185	688	1,012	275	217,837	(29,747)
National forest	14,847	3,835	3,145	3,002	2,231	1,519	1,386	619	515	379	250	493	137	32,366	(2,226)
Total	230,760	44,293	34,065	39,202	30,166	24,466	11,513	8,011	5,430	3,448	2,316	3,073	1,095	437,848	
Standard error	(23,118)	(4,170)	(3,131)	(3,391)	(2,423)	(2,191)	(993)	(799)	(587)	(512)	(336)	(307)	(157)	(29,700)	
Juniper savanna:															
Bureau of Land Management	17,252	1,884	2,395	1,042	966	1,048	420	451	149	155	112	60	14	25,948	(4,689)
Othe public	949	193	461	193	193	465	32	125	—	32	—	93	—	2,736	(1,455)
Private	31,979	4,495	1,339	2,273	1,353	1,813	498	400	208	281	16	250	—	44,904	(7,501)
National forest	420	157	171	102	93	110	53	47	25	6	10	40	10	1,244	(337)
Total	50,600	6,729	4,366	3,610	2,605	3,436	1,003	1,023	382	474	138	443	24	74,832	
Standard error	(6,472)	(1,891)	(1,146)	(869)	(703)	(831)	(237)	(288)	(109)	(134)	(70)	(177)	(10)	(8,359)	

Table 2—Estimated acres of juniper forest by tree-per-acre class and percentage of crown cover, eastern Oregon, 1999^a

Trees per acre	Crown cover percentage							Total	Standard error
	0-5	5-10	10-20	20-30	30-40	40-50	50+		
<i>Thousand acres</i>									
1-24	—	12	70	—	—	—	—	82	(40)
25-49	27	4	122	124	79	48	16	420	(96)
50-74	14	—	96	40	108	96	32	386	(85)
75-99	—	32	93	86	30	97	48	385	(90)
100-149	80	41	80	80	94	163	240	777	(116)
150-199	44	—	48	—	48	48	207	396	(79)
200+	16	—	32	112	110	80	390	741	(120)
Total	181	89	541	441	470	532	932	3,187	
Standard error	(64)	(39)	(111)	(98)	(94)	(99)	(111)	(169)	

— = less than 500 acres.

^a Does not include National Forest System land. Standard error in parentheses.

Table 3—Estimated area of western juniper forest by forest type class, county, and owner class for eastern Oregon, 1999^a

County	National forest		Bureau of Land Management		Other public		Private		Total		1936 ^b	County area
	Forest	Savanna	Forest	Savanna	Forest	Savanna	Forest	Savanna	Forest	Savanna		
<i>Thousand acres</i>												
Baker	11	2	32	—	—	—	80	294	123 (53)	295 (149)	20	1,964
Crook	42	2	287	107	32	—	424	242	785 (118)	351 (121)	509	1,907
Deschutes	—	—	176	88	16	32	32	13	224 (69)	133 (54)	329	1,932
Gilliam	—	—	—	—	—	—	16	32	16 (16)	32 (23)	—	771
Grant	76	5	32	94	—	—	257	373	365 (78)	472 (119)	41	2,898
Harney	43	5	460	496	15	32	19	142	537 (105)	675 (141)	189	6,486
Jefferson	112	1	32	—	—	—	218	142	362 (66)	142 (57)	63	1,140
Klamath	38	10	109	3	—	—	118	—	265 (67)	13 (3)	106	3,804
Lake	42	5	214	279	16	29	80	182	352 (69)	495 (130)	222	5,207
Malheur	—	—	96	81	16	48	26	80	138 (52)	209 (69)	34	6,328
Morrow	4	—	—	—	—	—	—	—	4 (1)	— (—)	—	1,301
Sherman	—	—	—	—	—	—	—	16	— (—)	16 (16)	—	527
Wasco	—	—	—	32	—	—	48	202	48 (36)	234 (117)	2	1,524
Wheeler	6	2	96	16	—	—	238	151	340 (85)	169 (58)	50	1,097
Total	377	33	1,534	1,196	95	141	1,556	1,869	3,559	3,227	1,520	38,899
Standard error	(18)	(5)	(156)	(168)	(39)	(61)	(154)	(319)	(152)	(340)		

— = less than 500 acres.

^a Totals may be off owing to rounding. Standard error in parentheses.

^b Estimates of juniper extent based on a 1936 vegetation map from Oregon Department of Forestry.

Changes From the 1988 Inventory

In 1988, the population of plots to be sampled was drawn from photointerpreted points that had 10 percent or greater crown cover. Points that were determined to have less than 9 percent cover were not sampled on the ground. Plots representing nearly 800,000 acres of the 3 million acres determined to have less than 10 percent cover in 1988 had greater than 5 percent stocking when sampled on the ground in 1999. This represents the majority of the change from 2.2 million acres of juniper forest estimated in 1988 to the 3.3 million estimated in 1999. We estimated that over 2 million acres that had juniper present in 1999 were determined from aerial photos to have no juniper cover in 1988. Ninety percent of these acres were classified as juniper savanna in 1999.

Juniper Volume

The majority of the juniper volume is found on juniper forest lands, about 90 percent of the 744 million cubic feet. The BLM manages almost half of the total volume with private owners owning most of the rest (table 4). The volume for juniper in eastern Oregon is still relatively small, about half that of ponderosa pine outside of national forests of 1.51 billion cubic feet (Azuma et al. 2002). Juniper forest land is characterized by relatively low volumes per acre with greater than 64 percent of the area having less than 200 cubic feet per acre. The National Forest System lands are somewhat of an exception, where only 56 percent of the area falls into the 0 to 200 cubic feet classes (table 5). Gedney et al. (1999) described these areas as transitional forests where forest types are transitioning from pine/fir to juniper types. In these areas, the juniper tends to grow taller and with more volume per tree than in other juniper forests; however, these areas represent a small proportion of the juniper forest. The transitional areas are probably best described by their elevation; as elevation increases, juniper tends to give way to ponderosa pine and Douglas-fir.

Juniper forests tend to have few other tree species intermingled within them, except in these transitional zones. The volume of other species within juniper forest is estimated to be 80 million cubic feet with ponderosa pine accounting for 65 million and curlleaf mountain mahogany, Douglas-fir, and quaking aspen making up the remainder (table 6).

Table 4—Estimated gross volume of western juniper by type class, county, and owner class for eastern Oregon, 1999^a

County	National forest		Bureau of Land Management		Other public		Private		Total		Total
	Forest	Savanna	Forest	Savanna	Forest	Savanna	Forest	Savanna	Forest	Savanna	
<i>Million cubic feet</i>											
Baker	4	1	6	—	—	—	7	4	17 (7)	5 (3)	21
Crook	14	1	56	3	4	—	59	4	133 (25)	8 (4)	139
Deschutes	—	—	49	1	3	3	2	—	54 (20)	4 (4)	57
Gilliam	—	—	—	—	—	—	3	1	3 (3)	1 (1)	4
Grant	24	3	7	2	—	—	55	6	86 (18)	11 (3)	93
Harney	16	3	83	7	2	2	4	2	105 (26)	14 (4)	114
Jefferson	3	—	3	—	—	—	23	3	29 (9)	3 (2)	30
Klamath	6	1	32	—	—	—	31	—	69 (21)	1 (1)	69
Lake	7	1	54	6	6	—	23	10	90 (21)	17 (9)	109
Malheur	—	—	28	1	2	3	10	—	40 (19)	4 (2)	44
Wasco	—	—	—	1	—	—	5	4	5 (4)	5 (5)	10
Wheeler	2	—	9	—	—	—	28	1	38 (11)	1 (1)	38
Total	78	10	328	21	18	7	247	35	671 73	744	
Standard error	(5)	(1)	(42)	(5)	(8)	(4)	(33)	(10)	(45)(12)	(44)	

— = less than 500,000 cubic feet.

^aVolume equations for juniper were developed by Chittester and MacLean 1984. Standard error in parentheses.

Table 5—Estimated acres of juniper forest by volume per acre class and owner class, eastern Oregon, 1999^a

Volume per acre	Bureau of Land Management	National forest	Other public	Private	Total	Standard error
<i>Cubic feet</i>	----- <i>Thousand acres</i> -----					
0–99	350	150	—	683	1,183	(142)
100–199	470	64	80	462	1,076	(135)
200–299	421	67	—	205	693	(98)
300–399	128	49	—	64	241	(57)
400+	166	47	16	141	370	(71)
Total	1,535	377	96	1,556	3,563	
Standard error	(156)	(18)	(39)	(154)	(153)	

— = less than 500 acres.

^aStandard error in parentheses.

Table 6—Estimated volume of other species in juniper forest lands by owner class and species, eastern Oregon, 1999

Species	Bureau of Land Management	National forest	Private	Total
<i>Million cubic feet</i>				
Ponderosa pine	15	28	12	65
Douglas-fir	—	5	—	5
Curleaf mountain mahogany	3	—	3	6
Quaking aspen	—	—	4	4
Total	18	33	19	80

— = less than 500,000 cubic feet.

Biomass of juniper may be of more importance than the cubic foot volume. Biomass is calculated as dry weight of bole, branches, and bark and is given in table 7, by owner. Acres of juniper forest land by biomass class is given in table 8. A general rule-of-thumb relationship between percentage of crown cover and tons of dry weight biomass for trees greater than 5 inches in diameter at breast height (d.b.h.) was developed from FIA plot data and is given by the following equation:

$$\text{Biomass} = -0.258 + 16.42 \times \text{percent crown cover.}$$

$$R^2 = .63$$

$$\text{Standard error} = 1.98.$$

Table 7—Estimated biomass of western juniper trees greater than 5 inches in diameter by type class, county, and owner class for eastern Oregon, 1999^a

County	National forest		Bureau of Land Management		Other public		Private		Total		Total
	Forest	Savanna	Forest	Savanna	Forest	Savanna	Forest	Savanna	Forest	Savanna	
<i>Thousand tons</i>											
Baker	62	14	180	0	0	0	88	0	330(128)	14(11)	344
Crook	318	18	1,017	48	118	0	1,287	86	2,740(501)	152(60)	2,892
Deschutes	0	0	585	9	71	11	19	7	675(272)	27(16)	702
Gilliam	0	0	0	0	0	0	55	5	55(55)	5(5)	60
Grant	476	30	65	15	0	0	897	45	1,438(232)	90(24)	1,528
Harney	279	22	1,223	62	55	32	20	33	1,577(352)	149(44)	1,726
Jefferson	35	0	51	0	0	0	341	79	427(124)	79(41)	506
Klamath	161	27	590	0	0	0	715	0	1,466(414)	27(19)	1,493
Lake	227	9	924	52	48	0	473	96	1,672(345)	157(90)	1,829
Malheur	0	0	235	7	65	4	156	0	456(214)	11(8)	467
Wasco	0	0	0	6	0	0	41	61	41(32)	67(37)	108
Wheeler	20	0	244	0	0	0	670	10	934(279)	10(10)	944
Total	1,578	120	5,113	199	357	47	4,763	421	11,811	788	12,599
Standard error	(139)	(32)	(732)	(52)	(148)	(34)	(678)	(120)	(750)	(114)	(769)

^aBiomass estimates are dry weight including bole, bark and branch estimates. Foliage is not included. Standard error in parentheses.

Table 8—Estimated acres of juniper forest by biomass class and owner class, eastern Oregon 1999^a

Biomass per acre	Bureau of Land Management	National forest	Other public	Private	Total	Standard error
<i>Tons</i> ----- <i>Thousand acres</i> -----						
0-1	455	90	—	564	1,109	(104)
1-2	307	31	—	270	608	(107)
2-4	306	52	64	344	766	(98)
4-6	227	47	32	128	405	(71)
6-8	112	52	—	78	242	(44)
8+	128	104	—	172	404	(51)
Total	1,535	376	96	1,556	3,534	
Standard error	(156)	(18)	(39)	(154)	(153)	

— = less than 500 acres.

^aStandard error in parentheses.

Growth, Mortality, and Removals

Juniper tends to be a slow-growing species although some trees, especially in the transitional zone, can grow quite rapidly. Of the over 500 trees that were remeasured from the 1988 inventory, no juniper trees were harvested, and only 4 had died. The sample of trees is too small to get an accurate estimate of removals and mortality. Eighty-nine percent of the remeasured trees had an 11-year diameter increment of less than or equal to 2 inches and 65 percent have a height increment of less than or equal to 2 feet (figs. 2 and 3). The majority grew less than 1.5 feet.

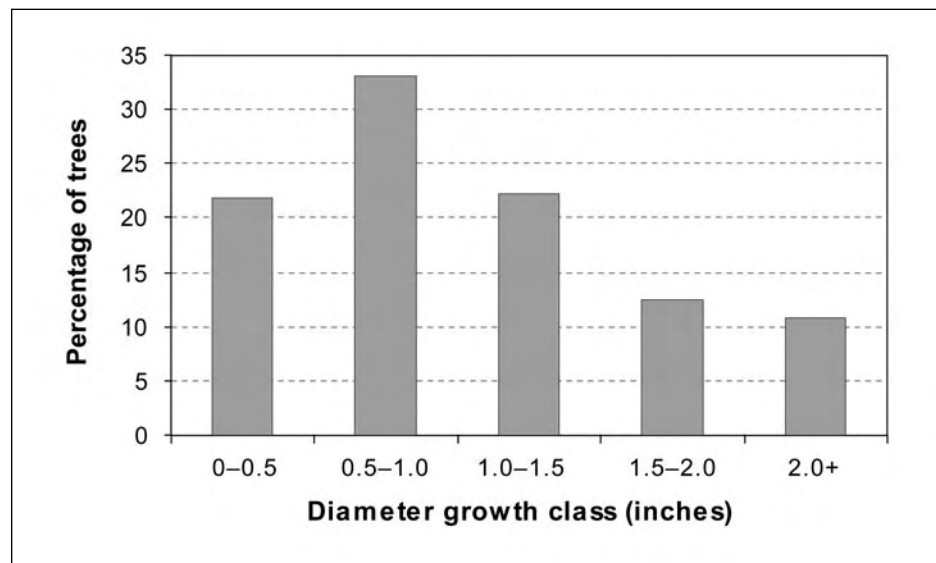


Figure 2—Eleven-year diameter growth increment on remeasured juniper trees.

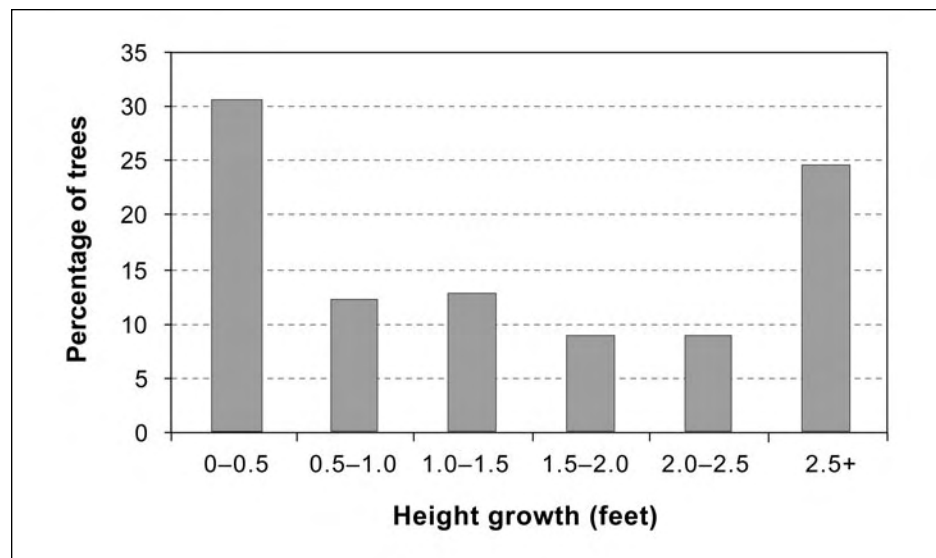


Figure 3—Eleven-year height increment on remeasured juniper trees.

Both the terminal and lateral leaders of juniper trees were evaluated for growth in the last growing season and grouped into three classes: slow growing (less than 1.9 inches per year), medium (1.9 to 3.9 inches per year), and (fast 3.9 inches or greater per year). Table 9 shows numbers of trees in terminal and lateral leader growth classifications by diameter class. Trees in the smaller diameter classes, mostly younger trees, show a greater proportion with fast-growing terminal leaders than trees in the largest diameter class (greater than 20 inches). The same pattern does not hold for lateral leaders with the small trees having a relatively even distribution across all growing classes; however, the largest diameter still has the greatest proportion of the trees in the slowest growth class.

Table 9—Number of trees by terminal and lateral leader growth class and diameter class, eastern Oregon, 1999

Diameter class	Growth rate			Total
	Slow <1.9	Medium 1.9 to 3.9	Fast 3.9 +	
	<i>Inches</i>			
Terminal growth				
Less than 5	680	825	1,295	2,800
5 to 9	54	93	356	503
9 to 20	218	244	489	951
Greater than 20	182	78	51	311
Lateral growth				
Less than 5	911	981	908	2,800
5 to 9	104	159	240	503
9 to 20	302	332	317	951
Greater than 20	217	64	30	311

^aDiameter taken at breast height, 4.5 feet. Growth in inches for the latest year.

Discussion

Juniper forests generally grow in an environment where moisture is the limiting factor in the potential of a site to be occupied by trees. The occupancy of the site can be hypothesized to be the limit of the lateral extension of roots (Hall 2004). As stands develop, they will slowly outcompete other vegetation including smaller junipers, sagebrush, and other understory vegetation. Because juniper tends to grow in multiaged stands, which makes computing an average stand age problematic, we used average stand size (tree d.b.h.) as a surrogate for stand age: as stand size increases, the average number of seedlings per acre tends to decrease and amount of crown cover tends to increase (table 10). In some cases, there can be stands with juniper over 100 years old that have no seedlings at all.

Table 10—Average number of seedlings per acre and cover in square meters of juniper trees by stand size class, eastern Oregon, 1999

Stand size class	Seedlings	Standard deviation	Cover	Standard deviation
Large (greater than 9 inches d.b.h.)	31.8	35.6	125.8	137.5
Medium (5 to 9 inches d.b.h.)	45.6	50.4	134.1	109
Small (less than 5 inches d.b.h.)	108.1	91.7	106.6	92.8
Nonstocked	25.3	38.8	13.8	16.9

d.b.h. = diameter at breast height.

The area of land classed as juniper forest has increased over the last 60 years from 420,000 acres in 1936 (Cowlin et al. 1942) to 3.3 million acres in 1999. In figure 1, 1936 vegetation cover layer shows juniper type, which includes what we define as savanna and forest, covering about 1.5 million acres. Our current estimate, 6.5 million acres, is over four times as much. Some of the changes may be accounted for by definitional changes, but certainly there has been an enormous increase. These increases can have a profound effect on the landscape, lowering grazing carrying capacities, intercepting precipitation, and changing the available wildlife habitat. Although some of the forest acres we inventoried do not have much crown cover, they will continue to increase in cover percentage as trees grow. As forest canopy cover becomes increasingly dense, the carrying capacity of rangelands will continue to decrease owing to moisture competition.

The clearing of juniper is expensive. Young et al. (1982) reported costs of \$31 to \$832 per acre for treatments ranging from chemical treatment to wood harvesting and slash removal. Common treatments for clearing juniper include cutting and leaving stems, mechanical clearing, and burning. To truly clear juniper land by using any of these treatments will likely require repeated treatments to eliminate new seedlings as they emerge. With private owners controlling over 50 percent of juniper forest and savanna lands, it is difficult to imagine substantial areas being cleared of juniper considering the cost of treatment and posttreatment followup.

Juniper stands in eastern Oregon tend to be multiaged with small trees intermingled with larger trees, so we used diameter range as a surrogate for age differences in an examination of both juniper forests and savanna. An interesting difference shows up in the percentage of land by diameter range (table 11). Forty-four percent of the savanna lands have a diameter range of less than 5 inches, but forest land has only 5 percent in this class. Conversely, the juniper forests have 52 percent of the area with a range greater than 20 inches compared to only 8 percent for the savanna. This suggests that much of the savanna is still developing into juniper forest.

Table 11—Estimated acres of juniper forest and savanna by range of plot diameter and juniper type, eastern Oregon, 1999^a

Range of diameter <i>Inches</i>	Forest		Savanna	
	<i>Thousand acres</i>	<i>Percent</i>	<i>Thousand acres</i>	<i>Percent</i>
0 to 4.99	158	5	1,415	44
5 to 9.99	175	5	450	14
10 to 14.99	506	15	374	12
15 to 19.9	744	22	716	22
20+	1,744	52	271	8

^aDiameter taken at breast height, 4.5 feet.

The expansion of juniper forests will probably continue to occur on lands that are now classified as juniper savanna. We estimate that more than 1 million acres of juniper savanna land has more than 25 trees per acre. Furthermore, plots representing one-third of the estimated acres of savanna had more than two seedlings on them. The evidence of seedlings on these lands suggests that juniper is still in an establishment stage, and that the probability of these lands continuing to increase in tree density is larger than for areas that have a single old juniper standing on it. Gedney et al. (1999) speculated that if all the juniper savanna lands converted to forest, there might be as much as 5 million acres of juniper forest in the future. If only half of the savanna lands continue to increase in tree density, the 5-million-acre number is quite reasonable, making juniper the forest type with the greatest area in eastern Oregon.

Metric Equivalents

1 acre = 0.405 hectare

1 acre = 4046.86 square meters

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

1 ton = 907 kilograms

Names of Trees

Common name	Scientific name ²
Softwoods:	
Douglas fir	<i>Pseudotsuga menziesii</i> (Mirb.) Franco
Ponderosa pine	<i>Pinus ponderosa</i> Dougl. ex Laws.
Western juniper	<i>Juniperus occidentalis</i> Hook.
Hardwoods:	
Quaking aspen	<i>Populus tremuloides</i> Michx.
Curleaf mountain mahogany	<i>Cercocarpus ledifolius</i> Nutt.

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²Nomenclature per Little 1979.

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