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Pinyon-Juniper Volume Equations for the Central Rocky Mountain States

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RESEARCH SUMMARY

Gross cubic foot volume equations are now available for pinyon-juniper and several other woodland species in Nevada, Idaho, Utah, Colorado, Wyoming, and South Dakota. The volume equations are based on data collected as a subsample of woodland inventories conducted by Federal and State land management agencies. In these inventories, volumes of 4,705 trees were estimated by a visual sampling method.

Use of the equations requires measurement of a tree's diameter at the root collar (DRC), total height, and number of basal stems. Thirteen equations, applicable to different parts of a species' range, are presented for Utah juniper, western juniper, Rocky Mountain juniper, oneseed juniper, singleleaf pinyon, pinyon, Gambel oak, bur oak, mountain-mahogany, and a group of woodland hardwoods.

A test of several equations against some local volume data revealed prediction errors up to 20 percent or more in half the cases. However, the equations should be adequate for use in large State-wide woodland inventories.

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Cover Photo: Over looking the main fork of Elk Creek near New Castle, CO.

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INTRODUCTION

Pinyon-juniper woodlands have a rich history of use. Native Americans in the West depended on the trees for fuel wood and food. In the late 1800's settlers cut an undocumented amount of pinyon (piñon) and juniper trees for lumber, mine props, fuel wood, charcoal, fenceposts, and other products for mining and ranching enterprises. However, during the past 40 to 50 years, the vast acreages of pinyon-juniper (P-J) woodlands were virtually ignored as a source of wood. In many areas, P-J removal by chaining was the accepted management practice for improving the land's grazing potential.

Today, P-J woodlands again are being eyed as a valuable resource for fuel wood and other uses. Increased energy demands and new requirements for sound ecological land management are creating new pressures and opportunities on approximately 48 million acres of P-J woodlands in the Western United States.

This concern prompted a joint effort by the U.S. Department of Agriculture's Forest Service (Forest Survey), the Department of the Interior's Bureau of Land Management and Bureau of Indian Affairs, and several State forestry departments to inventory P-J woodlands in Nevada, Idaho, Utah, Colorado, South Dakota, and Wyoming. Data provided by this joint inventory were the basis for the study described in this paper. This study's purpose was to develop individual tree cubic foot volume equations for pinyon, juniper, and other woodland tree species sampled by these inventories.

REVIEW OF PAST WORK

Constructing volume equations for pinyon and juniper trees presents unique problems. Unlike most conifers, excessive branching and multiple basal stems appear to be normal growth patterns for P-J. Researchers have tried a variety of measurements to describe P-J trees' bushy character, usually including crown and stem variables in their volume equations in addition to conventional variables of diameter and height.

Howell (1940) and Reveal (1944) conducted some of the first P-J volume studies in Arizona, New Mexico, and Nevada (summarized by Barger and Ffolliott in 1972). This work became P-J volume inventory standards used in Soil Conservation Service handbooks. These volume tables required measurement of diameter at breast height (d.b.h.), crown diameter, diameter of the tallest stem at 1 foot, and the amount of 4-foot wood segments at least 2 inches in diameter.

Mason and Hutchings (1967) offered tree foliage yield models based on crown dimensions for juniper in Utah. Storey (1969) constructed equations for predicting P-J biomass in southern California from measurements of crown dimensions, total height, and basal diameter at 1 foot above ground line. Estola (1979) developed P-J volume equations for southern Colorado and northern New Mexico using diameter at 1 foot above ground line, crown diameter, and total height as predictor variables. Also, in northern New Mexico, Clendenen (1979) developed P-J volume equations using diameter at the root collar (DRC), total height, and number of stems 3 inches in diameter within 1 foot above ground line. Gholz (1980) reported volume and biomass equations for juniper in western Oregon using only basal circumference of the stem as a predictor variable.

Tausch (1980) studied allometric relationships between plant parts for P-J in southwestern Utah. He did not provide volume equations but gave biological reasons for expecting P-J volume to be proportional to a function of DRC. He suggested the proportionality constant between volume and DRC would change with site quality. Miller and others (1981) and Meeuwig and Budy (1981) presented two ways for estimating P-J biomass for the same areas in Nevada. Their equations required measurement of crown diameter, d.b.h., number of stems greater than 3 inches, and diameter at 1 foot above ground line.

Weaver and Lund (1982) examined diameter-weight relationships for juniper in eastern Montana. Their results undermined Tausch's site-quality hypothesis by finding the same proportionality constant between tree weight and DRC on three different sites. Chittester and MacLean (1984) built an equation for estimating volume from d.b.h. and height for juniper in Oregon and California.

Ambrosia and others (1983) used pinyon and juniper volume equations in a Nevada Landsat study. Although they gave no reference source, these equations were identical to preliminary equations developed by Chojnacky (1981) for interim use in Nevada prior to this publication. These equations required DRC and total height measurements and were based on data described by Born and Chojnacky (in preparation).

Past work can be summarized by observing that everyone has measured pinyon and juniper differently. Only Tausch and Weaver gave biological reasoning for their work. The rest cited statistics associated with regression modeling as justification for their particular equation. The early work of Howell and Reveal was perhaps the most unique in that the number of 4-foot wood segments was used as a predictor variable. Some form of diameter measurement of the main stem was almost a unanimous choice for a predictor variable, but the exact place of this measurement has been a point of debate. Unfortunately, any direct comparison of all the P-J volume and biomass models would be futile unless a specific study were designed to take all the different measurements on the same P-J trees. Also, different standards were used for the minimum diameter of branch material included in the volume and biomass equations.

This study resulted from efforts in multiagency cooperation required by 1970's "environmental era" legislation. Its design mimicked that used by Clendenen (1979) in New Mexico. Because the study was closely linked to on-going inventories, it was not possible to carefully test past work or propose new ways to estimate pinyon-juniper volume. Instead, a few simple measurements—basal diameter, crown dimensions, total height, and number of stems—important in past work were made on a random subsample of all trees inventoried. This paper describes the search for the best volume equations from the data provided by the multiagency pinyon-juniper inventories.

DATA COLLECTION

Data were collected for P-J trees in Nevada, Idaho, Utah, Colorado, South Dakota, and Wyoming (figs. 8-11 in appendix A). The data also included some mountain-mahogany, oak, and other hardwood species found in the woodland types. Table 5 in appendix A contains a summary of the data collected by species and area. Quantiles of key variables and percentage of single stems are listed to illustrate the diversity of the data from the sample areas.

The trees were selected as a subsample of an inventory using 0.1-acre plots located on a 5 000 m grid (sometimes 2 500 or 10 000 m). Individual trees were sampled by diameter size class and species on each plot. At most, three trees of each species were selected in the diameter classes of 3 to 9.9 inches, 10 to 17.9 inches, and greater than 18 inches. Measurements recorded for each tree were diameter at root collar (DRC), total height (HT), maximum (CRMX) and minimum (CRMN) crown diameter, and number of stems (STEMS) 3 inches and larger within the first foot above DRC. If a tree forked at the ground line, an equivalent DRC (EDRC) was computed from the DRC of each fork:

$$\mathrm{EDRC} = \sqrt{\mathrm{DRC}_1^2 + \mathrm{DRC}_2^2 + \mathrm{DRC}_3^2 + \ldots}$$

A gross volume that included bark, wood, and dead branches (from ground line to 1.5-inch minimum branch diameters) was estimated for each tree by a visual technique. This volume estimate was obtained by visually classifying each stem and branch segment into a 2-inch by 2-foot class. Huber's formula was used to compute the volume of each segment. Segment volumes were then summed to obtain the volume of each tree.

The technique, called visual segmentation, has proved an adequate base for constructing volume equations. Born and Chojnacky (in preparation) compared volume equations built from visual estimates to actual volume measurements of destructively sampled trees. The equations using visual estimates predicted mean volume per acre within 0 to −9 percent of the actual measurements.

In theory, visual volume estimation should only result in random error among all the volume estimates. Random error measurements for a dependent variable (in this case the visual volume) present no difficulties when developing volume equations by regression (Neter and Wasserman 1974, p. 167). The consistent negative error found in the field test of visual volume estimation indicated a discrepancy between theory and practice, but not enough to justify increasing field sampling costs 10 to 20 times by felling trees to measure actual dimensions of each volume segment.

All field procedures used in this study were from manuals used by the USDA Forest Service, Forest Survey Unit in Ogden, UT (USDA 1983). All field personnel involved in the study used the same manuals, but it was not possible to uniformly monitor quality control for all agencies and all crews.

DATA ANALYSIS

The volume modeling process involved four steps: (1) identifying important predictor variables, (2) choosing an equation form, (3) selecting the number of equations, and (4) determining the reliability of the equations. Before any analysis was done, data were grouped by species into two large geographic areas. This was done at the request of the study designers. Nevada, Idaho, and Utah (west of the Wasatch, Parvant, and Tushar Mountains) were called the Great Basin States. Colorado, Wyoming, and the remainder of Utah were called the Colorado Plateau States. These two areas roughly corresponded to the geographic ranges of the two species of pinyon represented in the data (see fig. 9, appendix A). Collectively, the entire area was referred to as the central Rocky Mountain States. All analyses were done using the Statistical Analysis System (SAS) software package (SAS 1982).

Important Predictor Variables

Of all the variables available to predict volume, DRC is probably most important. All previous researchers used some type of diameter measurement in their volume and biomass equations. Tausch (1980) and Weaver and Lund (1982) also gave biological support to the hypothesis that a function of DRC is proportional to stem wood (although the two differ on the exact meaning of the proportionality constant in this relationship). Figure 1 shows the relationship between DRC and volume. This figure supported findings of past researchers on the importance of DRC and was characteristic of all P-J data available for this study.

An attempt was made to explain the variability (observed in fig. 1) in the DRC-volume relationship for all data groups listed in table 5 in appendix A. The additional variables, HT, CRMX, CRMN, and STEMS, were

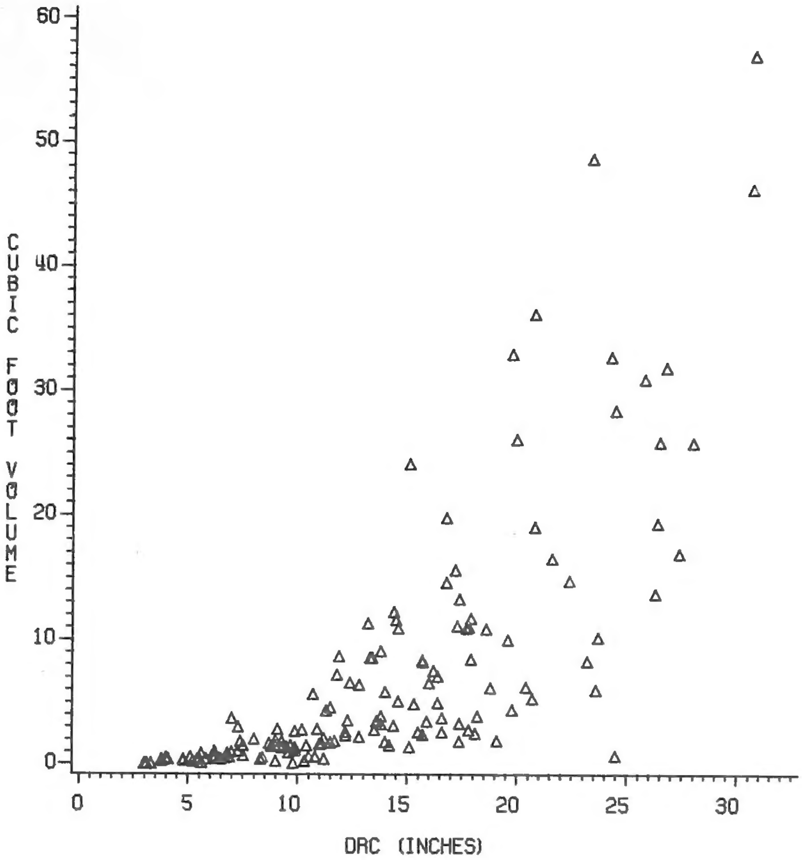

Figure 1.—Volume plotted against DRC for Utah juniper trees from the Moab BLM District.

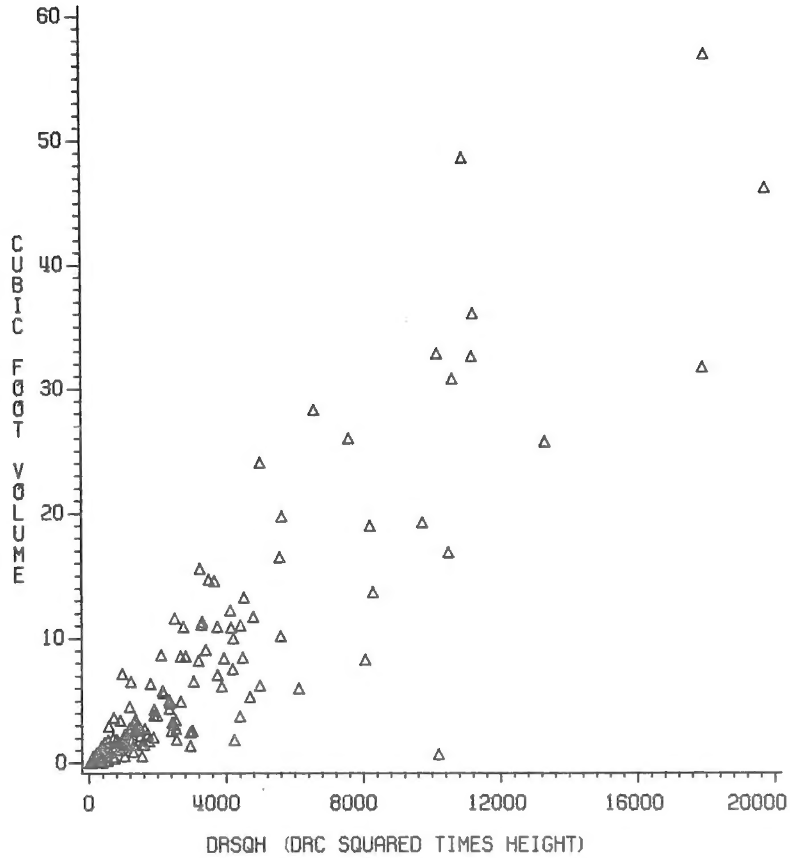

Figure 2.—Volume plotted against DRSQH for Utah juniper trees from the Moab BLM District.

analyzed in exploratory plots, multiple regressions, and stepwise regressions. Some benefit in volume predictions resulted from adding HT and STEMS into the volume prediction model, but most of the variability in the DRC-volume relationship could not be explained. The crown variables seemed to add very little to the volume prediction model, when DRC was already in the model. The DRC and HT variables were combined into a simple variable, DRSQH, by multiplying DRC squared times HT. A diameter and height combination variable that predicts volume well for commercial timber species worked as well for P-J. The STEMS variable was rendered almost useless because of an apparent interaction between stem sizes (not measured) and number of stems for a given P-J tree. However, it helped volume predictions somewhat to use a dummy variable to indicate whether a tree was multiple-stem or single-stem.

Equation Form

Modeling the DRSQH to volume relationship as a simple linear equation would be desirable for field use, but there were problems with this choice as illustrated in figure 2. Moab juniper data show the variance of volume increasing with tree size. This created a problem because the few largest trees disproportionately dominated the outcome of regression coefficient estimation.

The log transformation is commonly used to deal with increasing variance problems in regression. This transformation rescales data so that small and large trees have the same impact upon estimation of the regression coefficients. Transforming by applying fractional powers (such as $X^{1/4}$, $X^{1/3}$, $X^{1/2}$, and so forth) will also accomplish the same purpose as the log transformation. After examining several transformations on a subset of the data, the log and cube root transformations were selected for comparison on all data.

Figures 3 and 4 demonstrate the effect of the log and cube root transformations on the Moab juniper data. The log transformation appeared to compress the data too much for large trees, actually decreasing the variance with increasing tree size. The cube root transformation looked more reasonable.

All data for the other species from other areas responded to the transformations the same way the Moab data did. Additional plots of DRSQH against volume with stem counts overlaid showed some gain from inclusion of a dummy variable to distinquish single- from multiple-stem trees. Therefore, the final equation form selected for regression estimation of the coefficients was:

$$V_i^{1/3} = a + b(DRSQH_i)^{1/3} + c(STEM_i) + \epsilon_i \qquad (1)$$

where

V_i = visually estimated cubic foot volume to 1.5-inch minimum branch diameter (includes live wood, dead wood, and bark) of the ith tree

$DRSQH_i$ = DRC squared times total height of the ith tree

$STEM_i$ = 1 if a single-stem; 0 if a multiple-stem of the ith tree

a, b, c = coefficients to be estimated by regression

ϵ_i = random error (assumed to be zero on the average) of the ith tree.

During the analysis, I uncovered evidence for questioning the quality of some of the visual volume data.

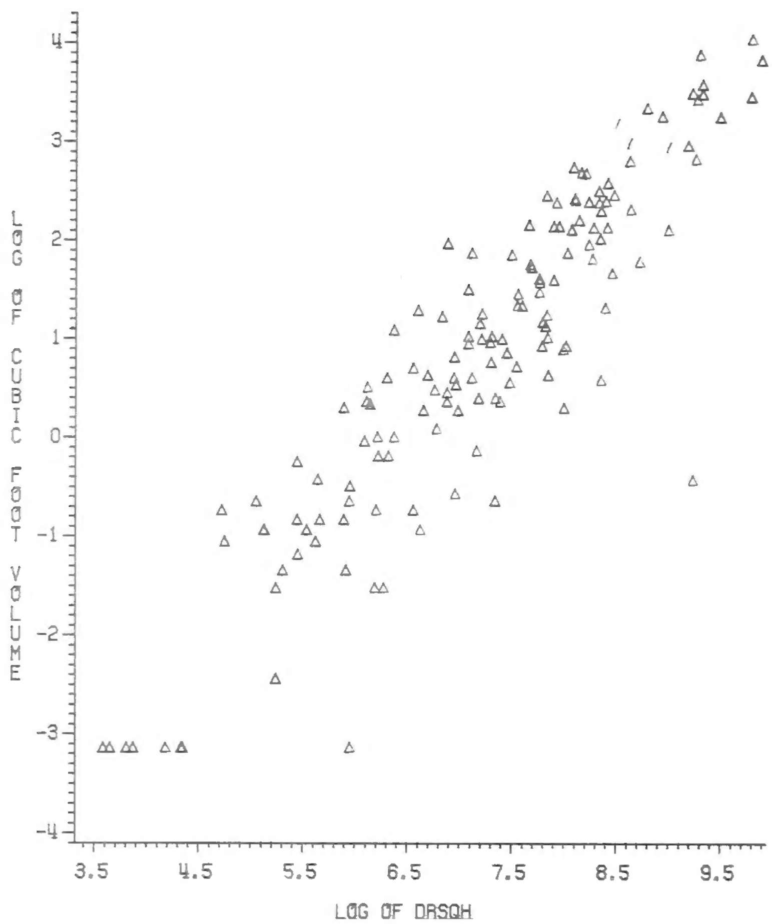

Figure 3.—Log transformation of volume plotted against DRSQH for Utah juniper trees from the Moab BLM District.

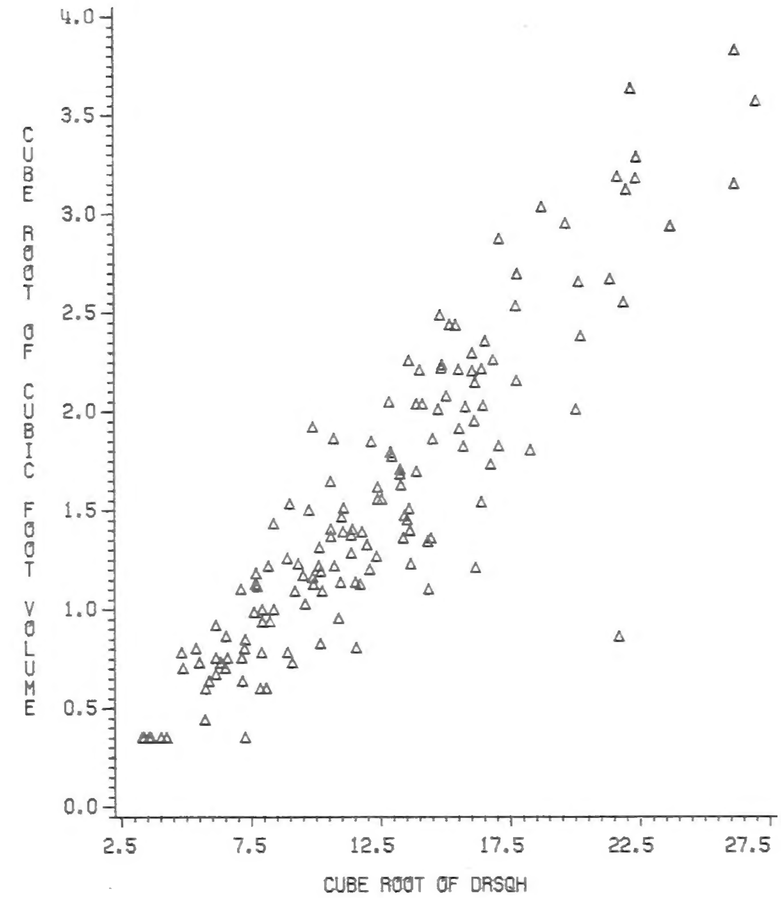

Figure 4.—Cube root transformation of volume plotted against DRSQH for Utah juniper trees from the Moab BLM District.

Rather than discard data or conduct a multiagency edit, I used a weighted regression method to minimize the effect of those data points that fell far from the regression line. The observations were weighted in regression by the following biweight function (Mosteller and Tukey 1977):

$$w_i = \begin{cases} (1-u_i^2)^2, & |u_i| \leq 1 \\ 0, & \text{elsewhere} \end{cases} \qquad (2)$$

with

$$u_i = (V_i - \hat{V}_i)/6M$$

where

w_i = biweight of the ith tree

V_i = visually estimated volume of the ith tree

$\hat{V}_i$ = predicted volume from the regression of the ith tree

M = the median of all $(V_i - \hat{V}_i)$ quantities (that is, the median residual from a regression).

Figure 5 illustrates the effects of biweight function on the residuals for Utah juniper from the Ely BLM District. The outlying data points are clearly minimized in this figure. However, the effect of the biweight function on parameter estimation was less dramatic. For example, the parameter estimates (in eq. 1) for the Ely data were $a = -0.036033$, $b = 0.135638$, and $c = -0.018677$ before biweighting and $a = -0.036549$, $b = 0.135689$, and $c = -0.018476$ after biweighting.

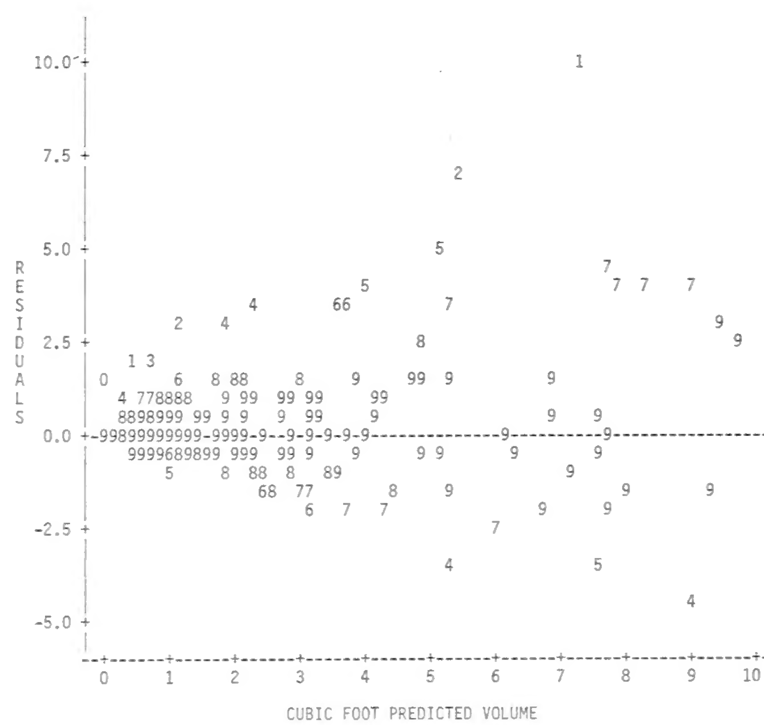

Figure 5.—A residual plot from a biweight regression of Utah juniper from the Ely BLM District. The numbers represent the percent of each observation used in the biweight regression: 0=0 to 4 percent, 1=5 to 14 percent...9=85 to 100 percent.

Number of Equations

Data were available for developing 33 volume equations, if each species from each area were kept separate. Combining some of these data sets was a difficult task because few good statistical methods exist for objective grouping. My approach used statistical tests between groups of regression coefficients and comparative plotting of regression equations.

Graybill (1976, p. 247) presented theory for testing whether or not a set of regression coefficients are similar. But, for the event of dissimilar coefficients in a set, Graybill gave no way to identify which coefficients are dissimilar. However, this approach was a good starting point.

The data were tested for full and reduced models for each species within the two large areas, the Great Basin States and Colorado Plateau States. A full model had a distinct set of regression coefficients for each BLM district or small area within the large area. A reduced model had only one set of coefficients for the entire large area.

Table 1 shows no significant difference between the full and reduced models for Utah juniper and pinyon in the Colorado Plateau States, and for western juniper in the Great Basin States. Data for these areas were grouped into their respective reduced models. Further analysis was done for those areas showing significant results in table 1. Graphs of the full models were examined to distinguish which areas should have separate volume equations.

Equations for the Great Basin States are shown in figures 6 and 7. The Utah juniper equations for the BLM districts of Ely, Elko, and Winnemucca (also

Table 1.—Analysis of variance tables comparing full and reduced volume models for pinyon and juniper

Source	Degrees of freedom	Sum of squares	Mean square	F-value	Prob > F
Utah Juniper in the Great Basin States					
Total	1,339	2,617.659			
Full model	24	2,573.803			
Reduced model	3	2,568.511			
Gain due to full model	21	5.292	0.2520	7.56	0.0001*
Error	1,315	43.856	.0334		
Utah Juniper in the Colorado Plateau States					
Total	397	892.891			
Full model	12	878.180			
Reduced model	3	877.799			
Gain due to full model	9	.381	.0423	1.11	.3544[ns]
Error	385	14.711	.0382		
Rocky Mountain Juniper in the Colorado Plateau States					
Total	194	359.158			
Full model	9	354.285			
Reduced model	3	353.088			
Gain due to full model	6	1.197	.1995	7.59	.0001*
Error	185	4.874	.0263		
Western Juniper in the Great Basin States					
Total	177	669.961			
Full model	6	663.288			
Reduced model	3	663.182			
Gain due to full model	3	.106	.0353	.91	.4375[ns]
Error	171	6.672	.0390		
Singleleaf Pinyon in the Great Basin States					
Total	1,445	2,931.848			
Full model	20	2,910.769			
Reduced model	3	2,909.535			
Gain due to full model	17	1.234	.0726	4.91	.0001*
Error	1,425	21.079	.0148		
Pinyon in the Colorado Plateau States					
Total	350	762.673			
Full model	12	753.441			
Reduced model	3	753.090			
Gain due to full model	9	.351	.0390	1.43	.1737[ns]
Error	338	9.232	.0273		

* This is the probability from an F-distribution (with degrees of freedom from the gain due to the full model and from the error) of getting a value larger than the reported F-value. For the α-level set at 0.05, these are significantly different.

[ns]For the α-level set at 0.05, the full and reduced models are not significantly different.

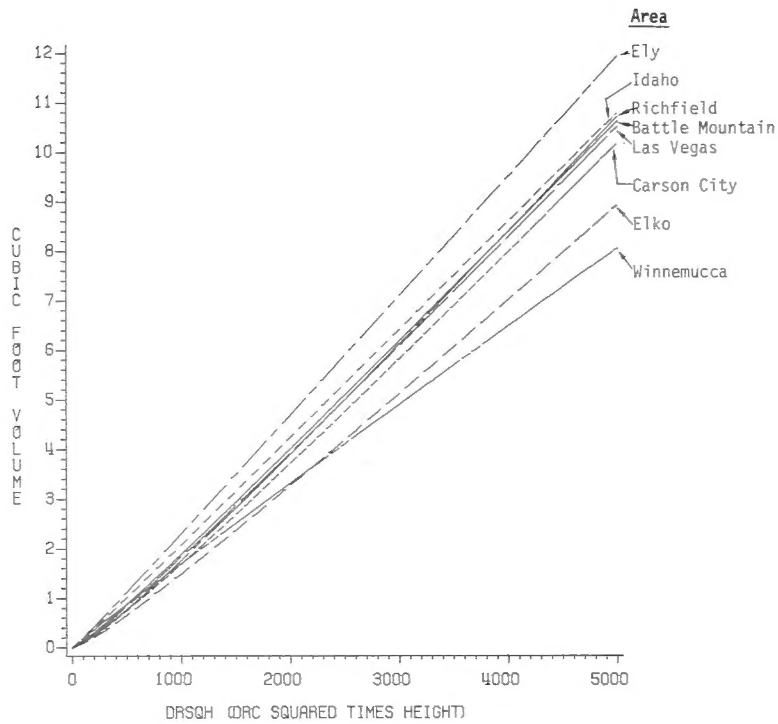

Figure 6.—Volume equations for multiple-stem Utah juniper in the Great Basin States. All area labels refer to BLM districts, except Idaho, which refers to southern Idaho.

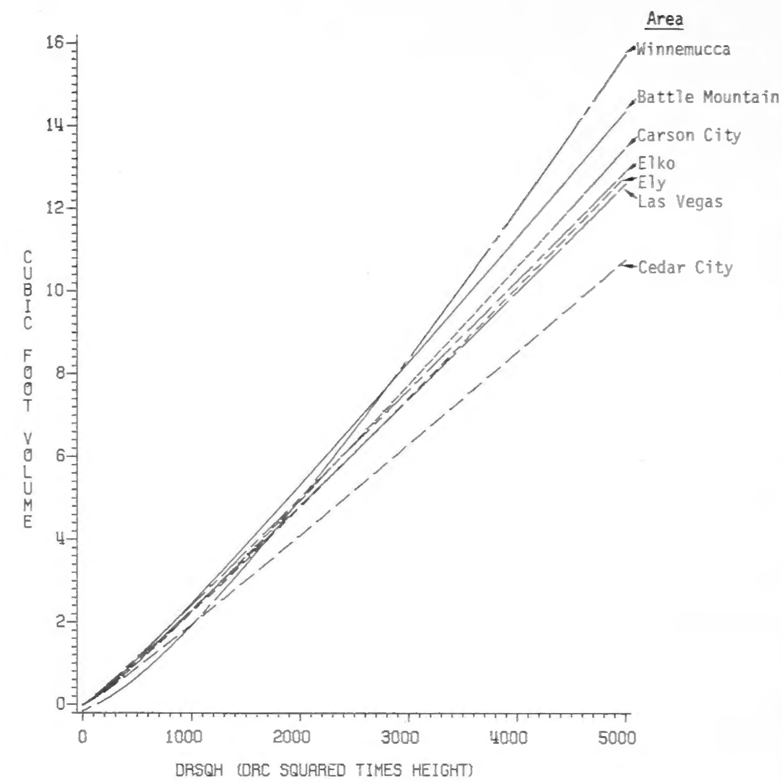

Figure 7.—Volume equations for single-stem singleleaf pinyon in the Great Basin States. The area labels refer to BLM districts.

includes Susanville BLM) looked different from the rest (fig. 6). I kept Ely and Winnemucca separate, but combined Elko with the rest of the Great Basin area. The Elko data contained a large percentage of single-stem trees, and in a graph of single-stem equations (not shown) the Elko data were not different. The Winnemucca and Cedar City singleleaf pinyon volume equations appeared distinct from the rest in figure 7. However, these differences were not meaningful because the Winnemucca data contained too few trees and the Cedar City data contained mostly small trees (DRSQH less than 2,000).

For the Colorado Plateau States, the table 1 results indicated further analysis for only Rocky Mountain juniper. Graphs of full models for Rocky Mountain juniper did show differences, but I combined all the data because of small sample sizes within groups.

The final number of P-J equations was based on the F-tests and on graphical analysis, as described for most of the data. In the case of mountain-mahogany, Rocky Mountain juniper, the oaks, and hardwoods, a small sample size dictated equations by species without consideration of geographic areas. Thirteen distinct volume equations were developed. A volume table for each equation is given in appendix B. Table 2 lists a guide for selecting a volume equation for each area and species.

Reliability of Equations

Additional statistical analysis should be done to examine reliability of regression equations when coefficients are estimated from transformed data, but equation predictions are retransformed for use. Such predictions are subject to transformation bias, and regression statistics in transformed units also can be misleading. I examined the bias of the cube root transformation, recomputed the R^2 statistic, and tested some of the volume equations against another data set. Duan (1983) presented a smearing estimator, a nonparametric retransformation method, that can be used to approximate the bias of any transformation. This was used to compute an approximate bias, defined as the difference between the predicted value from regression and the smearing estimator. The smearing estimator was calculated as:

$$SE = \frac{1}{n} \sum_{i=1}^{n} h(\underline{x}'\hat{\underline{\beta}} + w_i \hat{\epsilon}_i) \qquad (3)$$

where

SE = smearing estimator
$h(\cdot)$ = inverse of the transformation (the cubic function)
$\underline{x}'$ = row vector of regression predictor variables
$\hat{\underline{\beta}}$ = vector of regression coefficients
$\hat{\epsilon}_i$ = residual from regression for the ith tree
w_i = biweight of the ith tree (eq. 2)
n = number of trees.

The transformation bias is listed in table 3 as a percentage for several quantiles of the sample data. Because this bias is always negative, the volume equation will underestimate by the amount of the biases. No attempt was made to correct for the transformation bias, because the bias was relatively small and a bias adjustment that varied according to tree size would be complicated to apply.

Table 2.—A guide for using woodland volume equations and tables in the central Rocky Mountain States

State	Species	Area of application	Volume equation coefficients[1] a	b	c	Volume table number (in appendix B)
Colorado	Hardwoods[2]	entire State	−0.13822	0.121850	0	18
	Oneseed juniper	eastern Colorado	−.19321	.136101	0.038187	12
	Utah juniper	western Colorado	−.08728	.135420	−.019587	9
	Rocky Mountain juniper	entire State	.02434	.119106	0	11
	Pinyon	entire State	−.20296	.150283	.054178	14
	Gambel oak	entire State	−.13600	.145743	0	15
Idaho	Mountain-mahogany	southern Idaho	−.13363	.128222	.080208	17
	Hardwoods[2]	southern Idaho	−.13822	.121850	0	18
	Western juniper	southern Idaho	−.22048	.125468	.100092	10
	Utah juniper	southern Idaho	−.13386	.133726	.036329	6
	Rocky Mountain juniper	southern Idaho	.02434	.119106	0	11
	Singleleaf pinyon	southern Idaho[3]	−.14240	.148190	−.016712	13
Nevada	Mountain-mahogany	entire State	−.13363	.128222	.080208	17
	Western juniper	entire State	−.22048	.125468	.100092	10
	Utah juniper	Carson City, Battle Mountain, Elko, and Las Vegas[4]	−.13386	.133726	.036329	6
	Utah juniper	Ely[4]	−.03655	.135689	−.018476	7
	Utah juniper	Winnemucca and Susanville[4]	.04829	.114358	−.045779	8
	Singleleaf pinyon	entire State	−.14240	.148190	−.016712	13
South Dakota	Bur oak	Black Hills	.12853	.105885	0	16
Utah	Mountain-mahogany	eastern Utah	−.13363	.128222	.080208	17
	Utah juniper	eastern Utah	−.08728	.135420	−.019587	9
	Utah juniper	western Utah	−.13386	.133726	.036329	6
	Rocky Mountain juniper	eastern Utah	.02434	.119106	0	11
	Pinyon	eastern Utah	−.20296	.150283	.054178	14
	Singleleaf pinyon	western Utah	−.14240	.148190	−.016712	13
Wyoming	Mountain-mahogany	entire State	−.13363	.128222	.080208	17
	Hardwoods[2]	entire State	−.13822	.121850	0	18
	Utah juniper	entire State	−.08728	.135420	−.019587	9
	Rocky Mountain juniper	entire State	.02434	.119106	0	11
	Pinyon	entire State[3]	−.20296	.150283	.054178	14
	Bur oak	Black Hills	.12853	.105885	0	16

[1]The volume equation is: $V = [a + b(DRSQH)^{1/3} + c\ STEM]^3$, where: V = gross cubic foot volume of wood and bark to a 1.5-inch mbd; DRSQH = DRC (inches) squared times height (feet); STEM = 1 for single-stem trees; 0 for multiple-stem trees.
[2]This equation is a rough approximation for the following trees: willow, boxelder, maple, hawthorn, ash, locust, and cherry.
[3]Only a few trees were represented in the sample for this State.
[4]These are BLM districts in Nevada.

A recomputed R^2 statistic is listed for each volume equation in table 3. The R^2 statistic was recomputed in the original cubic foot volume scale using the following formula:

$$R^2 = 1 - \frac{(n-1) \sum_{i=1}^{n} (V_i - \hat{V}_i)^2}{(n-p) \sum_{i=1}^{n} (V_i - \bar{V})^2} \qquad (4)$$

where

$\hat{V}_i$ = predicted volume (ft^3) of the ith tree
V_i = visually estimated volume (ft^3) of the ith tree
$\bar{V}$ = mean of n visually estimated volumes (ft^3)
n = number of trees
p = number of model parameters (in this case p=3).

Table 3.—Recomputed R^2 and bias of the cube root transformation for several quantiles of the sample distribution

Volume equation for area or BLM district	Species	R^2	Quantile of sample	Predicted volume	Transformation bias[1]
				Ft³/tree	*Percent*
Great Basin States	Western juniper	0.76	25th	1.8	−5
			50th	5.8	−2
			75th	14.1	−1
			95th	51.6	−1
	Utah juniper	.76	25th	.9	−7
			50th	2.6	−3
			75th	6.3	−2
			95th	17.9	−1
	Singleleaf pinyon	.82	25th	.8	−4
			50th	2.5	−2
			75th	6.5	−1
			95th	20.6	0
Ely BLM	Utah juniper	.72	25th	.4	−9
			50th	1.2	−4
			75th	3.5	−2
			95th	13.9	−1
Winnemucca BLM	Utah juniper	.60	25th	.8	−11
			50th	2.5	−5
			75th	7.2	−3
			95th	25.7	−1
Colorado Plateau States	Oneseed juniper	.88	25th	.9	−8
			50th	2.3	−4
			75th	6.6	−2
			95th	21.5	−1
	Utah juniper	.77	25th	.9	−7
			50th	3.0	−3
			75th	7.4	−2
			95th	19.9	−1
	Rocky Mountain juniper	.70	25th	.8	−7
			50th	2.1	−4
			75th	5.5	−2
			95th	13.6	−1
	Pinyon	.84	25th	.8	−6
			50th	2.6	−3
			75th	6.4	−2
			95th	26.2	−1
Central Rocky Mountain States	Gambel oak	.86			
	Bur oak	.70			
	Mountain-mahogany	.77			
	Hardwoods	.77			

[1]Bias is the cube root inverse transformation of the volume prediction (from regression) minus the smearing estimator divided by the smearing estimator.

Data from another study were available for checking some of the equations for the Great Basin States (Born and Chojnacky, in preparation). More than 300 P-J trees were destructively sampled for volume. Table 4 shows the percentage error for predicting volume of individual trees grouped in diameter class intervals. The error was large: 20 percent or more in about half of the diameter classes.

In summary, the cube root transformation injected a negligible bias and most of the volume equations had a reasonable R^2. However, considerable volume prediction errors are likely to result from application of these equations in local areas.

Table 4.—Comparison of the Ely Utah juniper, Great Basin Utah juniper, and Great Basin singleleaf pinyon volume equations with actual volume data from Nevada and Utah BLM districts

BLM district	Species	Diameter class	Number of trees	Actual volume[1]	Predicted volume	Error[2]
		Inches		*---- Ft³/tree ----*		*Percent*
Battle Mountain	Utah juniper	3 – 9.9	5	0.83	1.07	30
		10 – 17.9	16	4.32	3.79	– 12
		> 18	3	14.22	12.78	– 10
	Singleleaf pinyon	3 – 9.9	26	1.81	1.60	– 12
		10 – 17.9	19	10.76	7.59	– 30
Carson City	Utah juniper	3 – 9.9	6	2.81	1.79	– 36
		10 – 17.9	10	5.15	4.68	– 9
		> 18	1	12.31	8.73	– 29
	Singleleaf pinyon	3 – 9.9	43	2.16	1.92	– 11
		10 – 17.9	26	15.57	10.79	– 29
		> 18	3	46.32	36.57	– 21
Elko	Utah juniper	3 – 9.9	24	1.11	1.16	4
		10 – 17.9	25	5.00	4.24	– 15
		> 18	3	13.04	11.96	– 8
	Singleleaf pinyon	3 – 9.9	10	1.33	1.22	– 8
		10 – 17.9	5	8.22	7.29	– 11
Ely	Utah juniper	3 – 9.9	19	0.65	0.95	47
		10 – 17.9	11	5.71	6.25	9
		> 18	7	16.30	19.57	20
	Singleleaf pinyon	3 – 9.9	17	1.21	1.05	– 13
		10 – 17.9	8	8.85	7.35	– 17
Las Vegas	Utah juniper	10 – 17.9	1	7.77	6.36	– 18
	Singleleaf pinyon	10 – 17.9	6	17.69	11.74	– 34
		> 18	1	55.03	29.02	– 47
Richfield	Utah juniper	3 – 9.9	2	2.05	1.75	– 15
		10 – 17.9	4	8.51	5.84	– 31
		> 18	2	20.53	15.17	– 26
Total	Utah juniper	3 – > 18	139	4.77	4.52	– 5
	Singleleaf pinyon	3 – > 18	164	7.29	5.42	– 26

[1]These are actual volumes computed from tree segments measured by destructively sampling each tree.
[2]Error is predicted volume minus actual volume divided by actual volume.

DISCUSSION

In this study, I searched through a large P-J data set and developed easy-to-use volume equations (and tables) with standardized measurements for predictor variables for the central Rocky Mountain States. However, there might be some concern about the reliability of these equations from the results of table 4. This concern is legitimate if the volume equations from this study are used for local areas. The discrepancy between the volume equation and the volume data given in table 4 clearly illustrates this concern. On the other hand, these volume equations are probably adequate for large Statewide woodland inventories. This is because the trees sampled in an inventory covering an entire State would likely represent most of the diverse tree forms used to obtain the regression coefficient listed in table 2. However, local inventories would be less likely to sample tree forms matching the tree form occurrence in this study. So results such as those in table 4 might be expected if these equations are used for local areas.

I see two possible approaches for future work on P-J volume equations. A more precise volume equation could be sought, or a simple model form such as the one presented in this study could be localized for each application.

Building a better P-J volume equation may require considerable effort. A stem measure that reflects both numbers and volume of each main stem of a multiple-stem tree may be one avenue for improvement. However, developing high precision broadly applicable P-J volume equations requires more knowledge of site and tree biology variables.

Development of local volume equations for each application is perhaps the best means, at present, to obtain precise P-J volume estimates. This is a fairly simple task as a subsample of trees from an inventory can easily be measured for volume by using visual segmentation (Born and Chojnacky, in preparation). A regression equation, volume equation can then be developed that reflects the diverse tree forms specific to the area of interest.

There is still much to learn about volume prediction in P-J woodlands. This study indicates need for more creative, scientific thinking in the future and less massive data collection.

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APPENDIX A

This appendix contains a glossary, a list of species mentioned in the text, maps showing the geographic location of the data (figs. 8 to 11), and summary statistics of the raw data by area and species (table 5).

Glossary of Terms

CRMX ... The maximum horizontal diameter of a tree's crown.

CRMN ... A tree's crown diameter that is roughly perpendicular to CRMX. (For an elliptical crown this is a minimum crown diameter.)

DRC ... Diameter of a tree at the root collar.

DRSQH ... DRC squared times height.

EDRC ... An equivalent diameter of a tree that forks at the root collar:

$$EDRC = \sqrt{\sum_{i=1}^{n} DRC_i^2}$$

Gross volume ... Volume of a tree's wood and bark (includes dead material) from DRC to a 1.5-inch minimum branch diameter.

HT ... Total height of a tree from DRC to the tip of the tallest stem perpendicular to DRC.

mbd ... Minimum branch diameter.

STEM ... A dummy variable with values: 1 for single-stem trees and 0 for multiple-stem trees.

Tree ... A woody plant species capable of yielding an aggregate 8 linear feet of wood and bark, from stem(s) and branch material at least 1.5 inches in diameter.

Woodland ... Forest land where tree cover is at least 90 percent non-timber (normally not used by the forest products industry) tree species.

Species List

Common name	Scientific name
Oneseed juniper	*Juniperus monosperma*
Rocky Mountain juniper	*Juniperus scopulorum*
Utah juniper	*Juniperus osteosperma*
Western juniper	*Juniperus occidentalis*
Pinyon	*Pinus edulis*
Singleleaf pinyon	*Pinus monophylla*
Mountain-mahogany	*Cercocarpus* sp.
Bur oak	*Quercus macrocarpa*
Gambel oak	*Quercus gambelii*
Hardwoods	
ash	*Fraxinus* sp.
boxelder	*Acer negundo*
cherry	*Prunus* sp.
hawthorn	*Crataegus* sp.
locust	*Robinia neomexicana*
maple	*Acer glabrum*
willow	*Salix* sp.

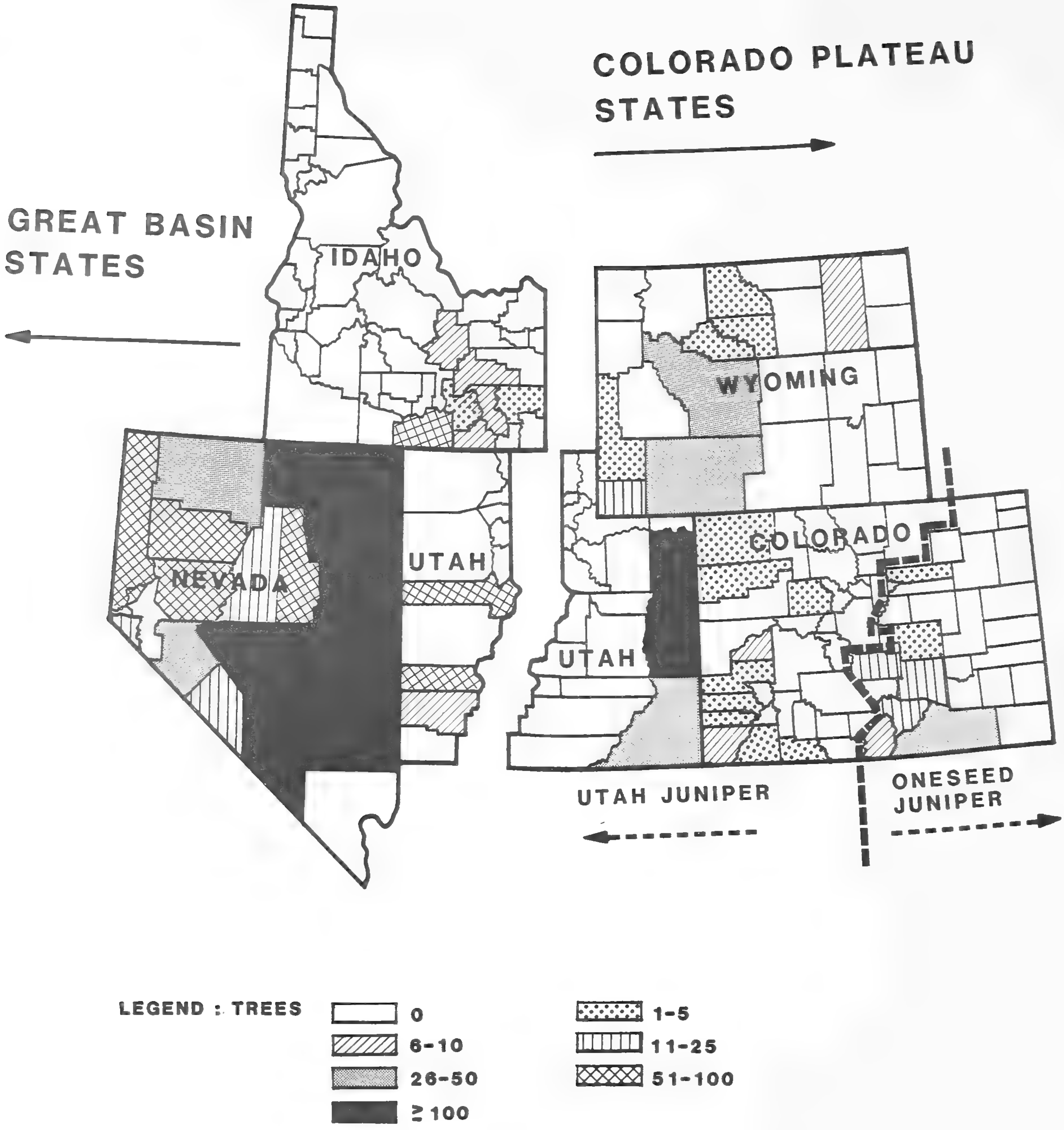

Figure 8.—Data distribution map of Utah juniper and oneseed juniper trees sampled.

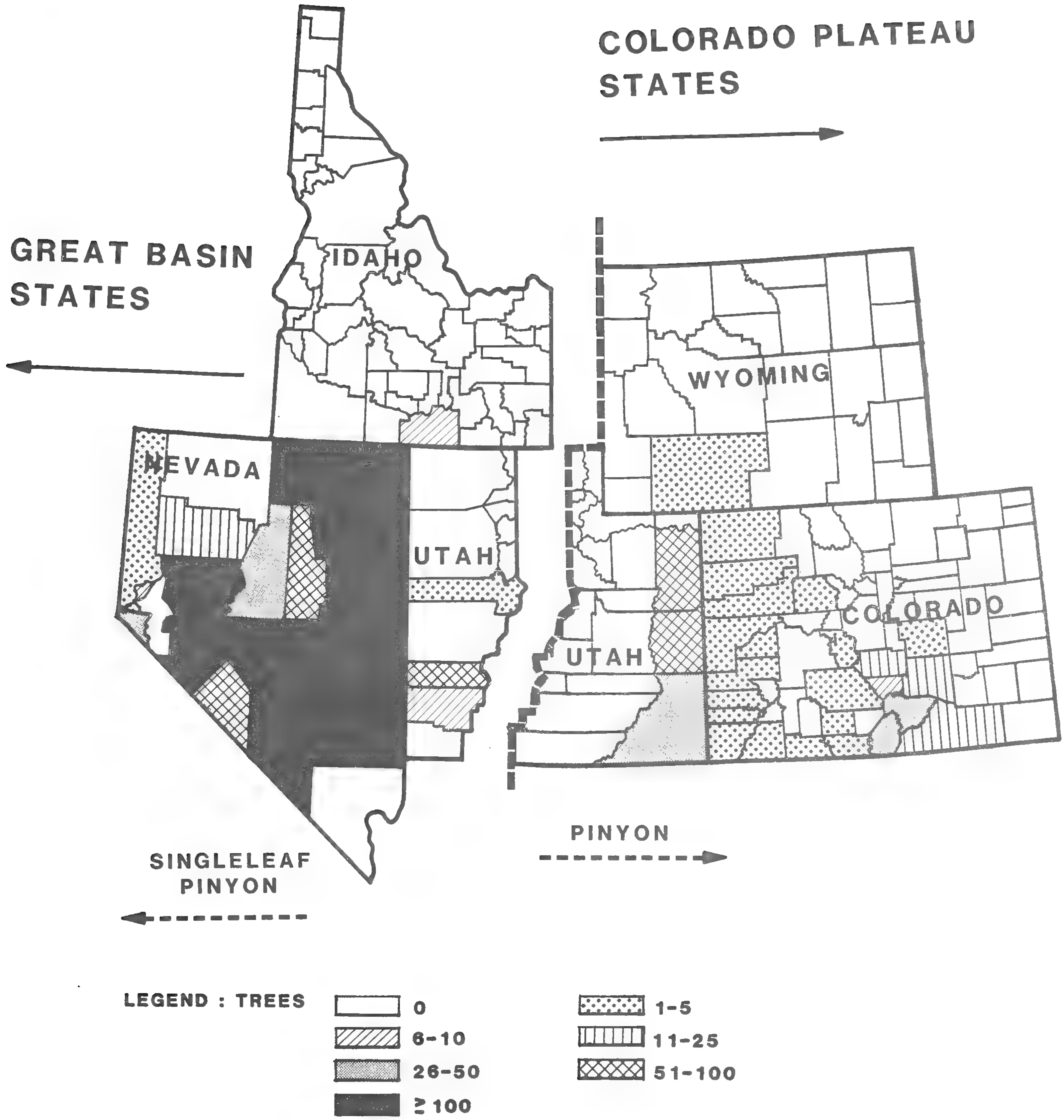

Figure 9.—Data distribution map of singleleaf pinyon and pinyon trees sampled.

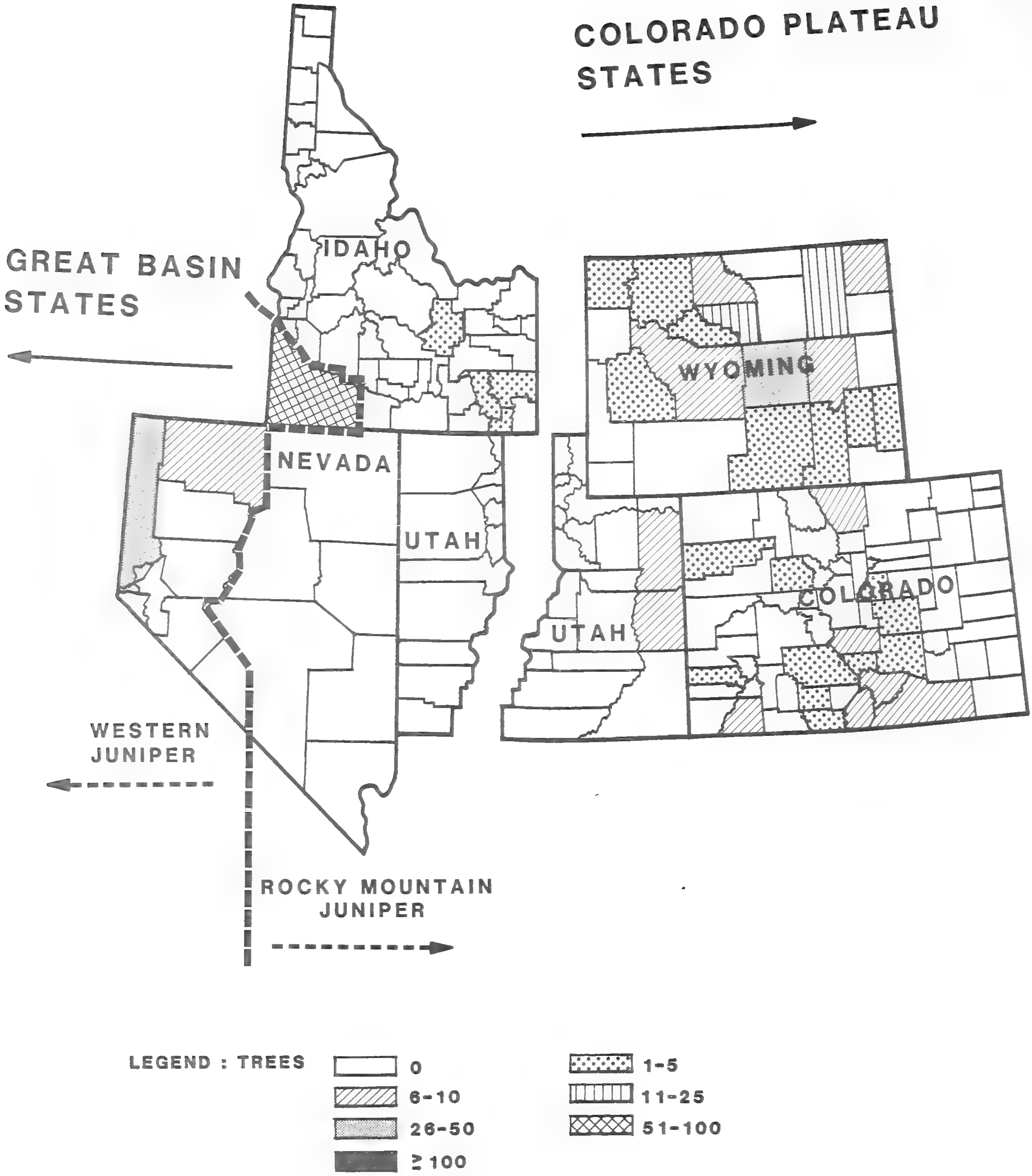

Figure 10.—Data distribution map of western juniper and Rocky Mountain juniper trees sampled.

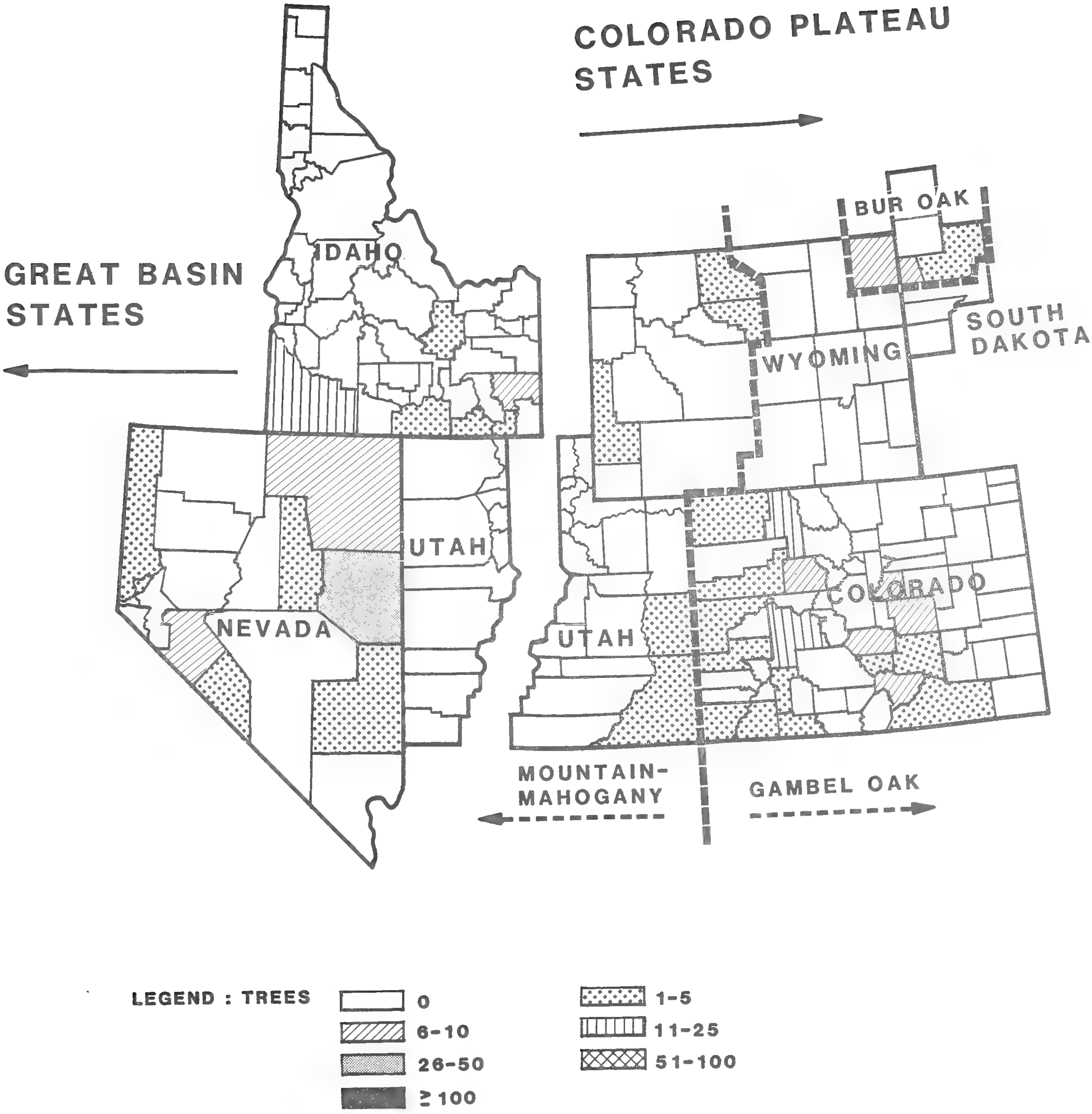

Figure 11.—Data distribution map of mountain-mahogany, Gambel oak, and bur oak sampled.

Table 5.—Summary statistics of volume (ft^3), DRC (inches), and height (ft) data by area and species

Area or BLM district	Species	Number of trees	Percentage[1] single stem	Variable	Mean	Quantiles 50th	Quantiles 75th	Quantiles 95th
Colorado	Oneseed juniper	100	40	Volume	6.0	2.2	7.5	24.2
				DRC	13.0	11.0	17.0	26.0
				Height	12.0	11.0	14.0	19.0
	Utah juniper	29	59	Volume	7.7	3.1	9.5	36.6
				DRC	13.0	12.0	17.0	29.0
				Height	14.0	14.0	18.0	27.0
	Rocky Mountain juniper	61	74	Volume	4.4	1.4	7.1	15.3
				DRC	10.0	9.0	13.0	19.0
				Height	14.0	13.0	17.0	23.0
	Pinyon	183	84	Volume	4.6	2.9	5.8	16.3
				DRC	9.0	9.0	12.0	19.0
				Height	14.0	13.0	17.0	25.0
	Gambel oak	94	93	Volume	0.8	0.3	0.6	3.6
				DRC	4.0	4.0	5.0	9.0
				Height	12.0	10.0	14.0	22.0
Idaho	Utah juniper	90	47	Volume	4.8	2.4	5.2	17.6
				DRC	11.0	10.0	14.0	21.0
				Height	12.0	12.0	15.0	18.0
	Rocky Mountain juniper	16	63	Volume	4.1	2.5	6.4	12.7
				DRC	13.0	12.0	16.0	27.0
				Height	15.0	14.0	20.0	25.0
	Western juniper	134	83	Volume	11.8	6.0	15.3	48.4
				DRC	14.0	13.0	18.0	30.0
				Height	22.0	22.0	27.0	37.0
Battle Mountain	Utah juniper	[2]117	58	Volume	3.9	1.4	3.7	15.3
				DRC	10.0	9.0	13.0	24.0
				Height	11.0	10.0	13.0	18.0
	Singleleaf pinyon	[2]228	87	Volume	5.1	2.0	6.3	20.3
				DRC	9.0	8.0	12.0	18.0
				Height	14.0	13.0	17.0	22.0
Carson City	Utah juniper	136	31	Volume	7.1	3.7	8.7	25.6
				DRC	14.0	13.0	19.0	26.0
				Height	12.0	12.0	15.0	20.0
	Singleleaf pinyon	518	76	Volume	7.5	3.5	9.2	27.4
				DRC	11.0	10.0	13.0	21.0
				Height	17.0	16.0	20.0	28.0
Elko	Utah juniper	[2]220	34	Volume	4.5	2.4	6.3	14.4
				DRC	11.0	10.0	15.0	23.0
				Height	12.0	11.0	14.0	19.0
	Singleleaf pinyon	[2]181	79	Volume	5.5	4.1	8.4	15.5
				DRC	10.0	10.0	13.0	16.0
				Height	16.0	15.0	19.0	24.0
Ely	Utah juniper	[2]295	40	Volume	3.6	1.5	3.9	16.8
				DRC	9.0	8.0	12.0	19.0
				Height	10.0	9.0	13.0	19.0
	Singleleaf pinyon	[2]313	78	Volume	3.5	1.1	3.7	15.8
				DRC	8.0	7.0	10.0	16.0
				Height	13.0	12.0	16.0	23.0
Las Vegas	Utah juniper	233	48	Volume	5.4	3.1	7.1	19.1
				DRC	12.0	11.0	16.0	23.0
				Height	13.0	12.0	16.0	21.0
	Singleleaf pinyon	149	86	Volume	4.7	1.5	5.9	18.8
				DRC	9.0	7.0	12.0	19.0
				Height	14.0	13.0	18.0	25.0
Winnemucca and Susanville	Utah juniper	168	37	Volume	8.1	2.9	8.5	36.2
				DRC	15.0	13.0	19.0	33.0
				Height	11.0	11.0	14.0	19.0
	Singleleaf pinyon	20	85	Volume	4.8	2.3	5.4	41.3
				DRC	9.0	8.0	11.0	22.0
				Height	13.0	15.0	16.0	20.0

(con.)

Table 5.—(con.)

Area or BLM district	Species	Number of trees	Percentage[1] single stem	Variable	Mean	Quantiles 50th	75th	95th
Nevada	Western juniper	48	54	Volume	20.1	3.8	15.6	106.4
				DRC	18.0	14.0	21.0	46.0
				Height	16.0	15.0	21.0	29.0
Cedar City	Singleleaf pinyon	[2]57	85	Volume	1.9	0.9	2.2	8.6
				DRC	7.0	6.0	9.0	13.0
				Height	12.0	11.0	15.0	22.0
Moab	Utah juniper	151	48	Volume	6.8	2.7	8.5	31.2
				DRC	13.0	12.0	17.0	26.0
				Height	11.0	11.0	14.0	20.0
	Pinyon	92	79	Volume	7.2	3.0	7.6	39.8
				DRC	10.0	9.0	13.0	20.0
				Height	15.0	15.0	20.0	30.0
Richfield	Utah juniper	96	56	Volume	5.0	3.0	6.3	20.9
				DRC	12.0	11.0	16.0	25.0
				Height	12.0	12.0	15.0	18.0
Vernal and Moab	Rocky Mountain juniper	18	67	Volume	3.6	3.5	5.8	11.1
				DRC	10.0	9.0	13.0	19.0
				Height	14.0	14.0	18.0	26.0
Vernal	Utah juniper	113	40	Volume	5.2	4.2	8.1	15.9
				DRC	13.0	12.0	18.0	23.0
				Height	10.0	10.0	12.0	19.0
	Pinyon	77	90	Volume	6.8	2.7	6.6	33.7
				DRC	10.0	10.0	14.0	21.0
				Height	14.0	12.0	17.0	28.0
Wyoming	Utah juniper	109	34	Volume	4.7	2.4	6.0	18.2
				DRC	13.0	12.0	18.0	27.0
				Height	9.0	8.0	11.0	14.0
	Rocky Mountain juniper	102	39	Volume	4.4	2.1	5.2	17.7
				DRC	12.0	11.0	16.0	25.0
				Height	11.0	9.0	13.0	21.0
Wyoming and South Dakota	Bur oak	14	79	Volume	2.9	1.7	5.4	9.3
				DRC	8.0	8.0	12.0	14.0
				Height	17.0	16.0	18.0	40.0
Central Rocky Mountain States	Hardwoods	29	34	Volume	12.1	2.2	15.7	98.7
				DRC	12.0	10.0	16.0	36.0
				Height	24.0	23.0	31.0	49.0
	Mountain-mahogany	126	37	Volume	2.2	1.0	2.6	7.1
				DRC	9.0	8.0	11.0	17.0
				Height	11.0	11.0	13.0	20.0

[1]The percentage of single-stem trees is based on all the data (including those trees deleted according to footnote 2).
[2]Data for more trees were available, but (for Nevada BLM readers, this included some 1978 to 1979 data) some multiple-stem trees were deleted due to DRC measurement inconsistencies.

APPENDIX B

This appendix contains gross cubic foot volume tables (tables 6 to 18). These include live and dead wood and bark from DRC to a 1.5-inch minimum branch diameter (mbd) for woodland tree species. The range of the data is outlined.

Table 6.—Gross cubic foot volume for Utah juniper in the Great Basin States

DRC	Basal stems	Height (feet) 4	6	8	10	12	14	16	18	20	25	30
Inches		Cubic feet										
4	Single	0.08	0.14	0.19	0.25	0.31	0.36	0.42	0.48	0.55		
	Multiple	0.06	0.11	0.16	0.21	0.26	0.31	0.37	0.42	0.48		
6	Single	0.22	0.35	0.48	0.62	0.76	0.90	1.05	1.19	1.33	1.70	2.07
	Multiple	0.18	0.30	0.42	0.55	0.67	0.81	0.94	1.07	1.21	1.55	1.90
8	Single	0.42	0.67	0.92	1.17	1.43	1.69	1.95	2.22	2.48	3.15	3.83
	Multiple	0.37	0.59	0.82	1.06	1.30	1.54	1.79	2.04	2.29	2.93	3.57
10	Single	0.70	1.09	1.50	1.91	2.32	2.73	3.15	3.58	4.00	5.07	6.14
	Multiple	0.62	0.98	1.36	1.74	2.13	2.53	2.93	3.33	3.73	4.75	5.78
12	Single	1.05	1.63	2.22	2.82	3.42	4.03	4.65	5.26	5.88	7.44	9.00
	Multiple	0.94	1.48	2.04	2.61	3.18	3.76	4.35	4.94	5.53	7.03	8.54
14	Single	1.46	2.27	3.09	3.91	4.75	5.59	6.43	7.28	8.13	10.27	12.42
	Multiple	1.33	2.09	2.86	3.65	4.45	5.25	6.06	6.88	7.70	9.77	11.85
16	Single	1.95	3.02	4.10	5.19	6.30	7.40	8.52	9.63	10.75	13.57	16.40
	Multiple	1.79	2.80	3.83	4.87	5.93	7.00	8.07	9.15	10.23	12.96	15.71
18	Single		3.88	5.26	6.66	8.06	9.48	10.89	12.32	13.75	17.34	20.94
	Multiple		3.62	4.94	6.28	7.63	9.00	10.37	11.75	13.13	16.62	20.12
20	Single		4.85	6.57	8.31	10.05	11.81	13.57	15.34	17.11	21.57	26.04
	Multiple		4.55	6.20	7.87	9.55	11.25	12.96	14.68	16.40	20.73	25.09
22	Single		5.93	8.03	10.14	12.27	14.40	16.55	18.70	20.85	26.26	31.70
	Multiple		5.58	7.60	9.64	11.70	13.77	15.85	17.94	20.04	25.31	30.62
24	Single		7.13	9.63	12.16	14.70	17.26	19.82	22.39	24.97	31.43	37.92
	Multiple		6.73	9.15	11.59	14.06	16.54	19.03	21.53	24.05	30.36	36.71
26	Single			11.39	14.37	17.36	20.37	23.39	26.42	29.45	37.07	44.71
	Multiple			10.84	13.73	16.64	19.57	22.51	25.46	28.42	35.87	43.35
28	Single			13.29	16.76	20.25	23.75	27.26	30.78	34.31	43.17	52.06
	Multiple			12.69	16.05	19.45	22.86	26.29	29.73	33.18	41.84	50.55
30	Single			15.34	19.34	23.35	27.39	31.43	35.49	39.55	49.74	59.97
	Multiple			14.68	18.56	22.47	26.41	30.36	34.32	38.30	48.28	58.32
35	Single				26.60	32.11	37.63	43.17	48.72	54.29	68.23	82.23
	Multiple				25.64	31.02	36.42	41.84	47.28	52.74	66.43	80.18

Volume = $[-0.13386 + 0.133726(DRSQH)^{1/3} + 0.036329(STEM)]^3$ where: DRSQH = DRC squared times height; STEM = 1 if single, 0 if multiple.

Table 7.—Gross cubic foot volume for Utah juniper in the Ely BLM District

DRC	Basal stems	Height (feet)													
		4	6	8	10	12	14	16	18	20	25	30	35	40	50
Inches		*Cubic feet*													
4	Single	0.12	0.18	0.25	0.32	0.39	0.45	0.52	0.59	0.67					
	Multiple	0.13	0.20	0.27	0.34	0.42	0.49	0.56	0.63	0.71					
6	Single	0.28	0.44	0.59	0.75	0.91	1.08	1.24	1.40	1.57	1.98	2.39			
	Multiple	0.31	0.47	0.63	0.80	0.97	1.14	1.30	1.47	1.64	2.07	2.49			
8	Single	0.52	0.81	1.09	1.38	1.67	1.97	2.26	2.56	2.85	3.60	4.34	5.09	5.84	
	Multiple	0.56	0.86	1.15	1.45	1.75	2.06	2.36	2.66	2.97	3.73	4.49	5.26	6.03	
10	Single	0.84	1.29	1.75	2.21	2.67	3.13	3.60	4.06	4.53	5.70	6.88	8.06	9.25	11.62
	Multiple	0.89	1.36	1.83	2.30	2.78	3.25	3.73	4.20	4.68	5.88	7.08	8.29	9.49	11.91
12	Single		1.89	2.56	3.22	3.89	4.57	5.24	5.92	6.60	8.30	10.01	11.72	13.44	16.88
	Multiple		1.98	2.66	3.35	4.03	4.72	5.41	6.10	6.79	8.53	10.27	12.01	13.75	17.24
14	Single			3.52	4.44	5.35	6.28	7.20	8.13	9.06	11.39	13.72	16.06	18.41	23.12
	Multiple			3.65	4.59	5.53	6.47	7.41	8.35	9.30	11.67	14.04	16.42	18.80	23.57
16	Single			4.64	5.84	7.05	8.26	9.47	10.69	11.91	14.96	18.03	21.10	24.18	30.34
	Multiple			4.80	6.03	7.26	8.49	9.72	10.96	12.20	15.30	18.41	21.52	24.64	30.89
18	Single			5.92	7.45	8.98	10.52	12.06	13.61	15.15	19.03	22.92	26.82	30.73	38.56
	Multiple			6.10	7.66	9.22	10.79	12.36	13.93	15.50	19.43	23.37	27.32	31.28	39.19
20	Single			7.35	9.25	11.15	13.05	14.96	16.88	18.79	23.60	28.41	33.24	38.07	47.76
	Multiple			7.56	9.49	11.43	13.36	15.30	17.24	19.19	24.06	28.93	33.82	38.70	48.49
22	Single				11.24	13.55	15.86	18.18	20.50	22.83	28.65	34.50	40.35	46.21	57.95
	Multiple				11.52	13.87	16.22	18.57	20.92	23.28	29.18	35.09	41.00	46.92	58.78
24	Single				13.44	16.19	18.95	21.71	24.48	27.26	34.21	41.17	48.15	55.13	69.13
	Multiple				13.75	16.55	19.34	22.15	24.95	27.76	34.79	41.83	48.88	55.94	70.07
26	Single					19.06	22.31	25.56	28.82	32.08	40.25	48.44	56.64	64.85	81.30
	Multiple					19.46	22.75	26.05	29.34	32.64	40.90	49.18	57.46	65.75	82.35
28	Single					22.17	25.95	29.73	33.51	37.30	46.79	56.30	65.82	75.36	94.47
	Multiple					22.62	26.44	30.26	34.09	37.92	47.51	57.12	66.73	76.35	95.62
30	Single						29.86	34.21	38.56	42.91	53.82	64.75	75.70	86.66	108.62
	Multiple						30.40	34.79	39.19	43.60	54.62	65.65	76.70	87.75	109.89
35	Single						40.86	46.79	52.73	58.68	73.57	88.49	103.43	118.39	148.34
	Multiple						41.52	47.51	53.51	59.52	74.55	89.60	104.66	119.73	149.90
40	Single							61.35	69.13	76.92	96.42	115.95	135.50	155.07	194.27
	Multiple							62.22	70.07	77.93	97.59	117.27	136.97	156.68	196.13
50	Single							96.42	108.62	120.83	151.40	182.01	212.66	243.33	304.74
	Multiple							97.59	109.89	122.19	152.98	183.80	214.64	245.50	307.26

Volume $= [-0.03655 + 0.135689(\text{DRSQH})^{1/3} - 0.018476(\text{STEM})]^3$ where: { DRSQH = DRC squared times height; STEM = 1 if single, 0 if multiple.

Table 8.—Gross cubic foot volume for Utah juniper in the Winnemucca and Susanville BLM Districts

DRC	Basal stems	Height (feet) 4	6	8	10	12	14	16	18	20	25	30
Inches		*Cubic feet*										
4	Single	0.10	0.15	0.19	0.24	0.29	0.34	0.39	0.44	0.48		
	Multiple	0.13	0.19	0.24	0.30	0.35	0.41	0.46	0.52	0.57		
6	Single	0.22	0.33	0.44	0.54	0.65	0.76	0.87	0.98	1.08	1.36	
	Multiple	0.27	0.40	0.52	0.64	0.76	0.88	1.00	1.12	1.24	1.53	
8	Single	0.39	0.58	0.77	0.96	1.16	1.35	1.54	1.73	1.93	2.41	
	Multiple	0.46	0.68	0.89	1.10	1.31	1.52	1.73	1.94	2.15	2.66	
10	Single	0.60	0.90	1.20	1.51	1.81	2.11	2.41	2.71	3.01	3.76	
	Multiple	0.71	1.04	1.37	1.69	2.02	2.34	2.66	2.98	3.30	4.10	
12	Single	0.87	1.30	1.73	2.17	2.60	3.03	3.46	3.90	4.33	5.41	6.49
	Multiple	1.00	1.47	1.94	2.40	2.87	3.33	3.79	4.25	4.70	5.84	6.98
14	Single	1.18	1.77	2.36	2.95	3.53	4.12	4.71	5.30	5.89	7.36	8.83
	Multiple	1.34	1.98	2.61	3.24	3.86	4.49	5.11	5.73	6.35	7.89	9.43
16	Single		2.31	3.08	3.85	4.62	5.38	6.15	6.92	7.69	9.61	11.52
	Multiple		2.56	3.38	4.19	5.01	5.82	6.62	7.43	8.23	10.24	12.24
18	Single		2.92	3.90	4.87	5.84	6.81	7.78	8.75	9.73	12.15	14.58
	Multiple		3.21	4.25	5.27	6.30	7.32	8.33	9.35	10.36	12.89	15.42
20	Single		3.61	4.81	6.01	7.21	8.41	9.61	10.80	12.00	15.00	18.00
	Multiple		3.94	5.21	6.47	7.73	8.99	10.24	11.49	12.74	15.85	18.96
22	Single		4.36	5.82	7.27	8.72	10.17	11.62	13.07	14.52	18.15	21.77
	Multiple		4.74	6.27	7.79	9.31	10.83	12.34	13.85	15.35	19.11	22.86
24	Single			6.92	8.65	10.37	12.10	13.83	15.55	17.28	21.59	25.91
	Multiple			7.43	9.24	11.04	12.84	14.63	16.42	18.21	22.68	27.13
26	Single			8.12	10.15	12.17	14.20	16.22	18.25	20.28	25.34	30.40
	Multiple			8.69	10.80	12.91	15.02	17.12	19.22	21.31	26.54	31.76
28	Single			9.41	11.76	14.11	16.46	18.81	21.16	23.51	29.38	35.26
	Multiple			10.04	12.49	14.93	17.37	19.80	22.23	24.66	30.71	36.75
30	Single			10.80	13.50	16.20	18.90	21.59	24.29	26.99	33.73	40.47
	Multiple			11.49	14.30	17.10	19.89	22.68	25.46	28.24	35.18	42.11
35	Single				18.37	22.04	25.71	29.38	33.05	36.72	45.90	55.07
	Multiple				19.35	23.14	26.93	30.71	34.49	38.26	47.68	57.08
40	Single					28.79	33.58	38.37	43.16	47.96	59.94	71.92
	Multiple					30.09	35.03	39.96	44.88	49.79	62.07	74.32
50	Single							59.94	67.42	74.91	93.63	112.34
	Multiple							62.07	69.72	77.38	96.49	115.57

Volume = $[0.04829 + 0.114358(DRSQH)^{1/3} - 0.045779(STEM)]^3$ where: DRSQH = DRC squared times height; STEM = 1 if single, 0 if multiple.

Table 9.—Gross cubic foot volume for Utah juniper in Colorado Plateau States

DRC	Basal stems	Height (feet) 4	6	8	10	12	14	16	18	20	25	30
Inches		*Cubic feet*										
4	Single	0.08	0.14	0.19	0.25	0.31	0.37	0.43	0.49	0.55		
	Multiple	0.09	0.15	0.21	0.27	0.33	0.40	0.46	0.53	0.59		
6	Single	0.22	0.35	0.49	0.63	0.77	0.91	1.06	1.21	1.36	1.73	2.11
	Multiple	0.24	0.38	0.53	0.67	0.82	0.97	1.12	1.28	1.43	1.82	2.21
8	Single	0.43	0.68	0.93	1.19	1.46	1.72	1.99	2.26	2.53	3.22	3.92
	Multiple	0.46	0.72	0.99	1.26	1.53	1.81	2.09	2.36	2.65	3.35	4.06
10	Single	0.71	1.11	1.52	1.94	2.36	2.79	3.22	3.66	4.09	5.19	6.29
	Multiple	0.75	1.17	1.60	2.03	2.47	2.91	3.35	3.80	4.24	5.37	6.50
12	Single	1.06	1.66	2.26	2.88	3.50	4.13	4.76	5.39	6.03	7.63	9.24
	Multiple	1.12	1.74	2.36	3.00	3.64	4.28	4.92	5.57	6.22	7.86	9.50
14	Single	1.49	2.31	3.15	4.00	4.86	5.73	6.60	7.47	8.35	10.55	12.77
	Multiple	1.57	2.42	3.28	4.15	5.03	5.92	6.80	7.70	8.59	10.84	13.09
16	Single	1.99	3.08	4.20	5.32	6.45	7.59	8.74	9.89	11.05	13.95	16.87
	Multiple	2.09	3.21	4.35	5.50	6.66	7.82	8.99	10.16	11.34	14.30	17.26
18	Single	2.57	3.97	5.39	6.83	8.27	9.73	11.19	12.66	14.13	17.84	21.56
	Multiple	2.68	4.12	5.57	7.04	8.52	10.00	11.49	12.98	14.48	18.24	22.02
20	Single	3.22	4.97	6.74	8.52	10.32	12.13	13.95	15.78	17.61	22.20	26.82
	Multiple	3.35	5.14	6.95	8.77	10.61	12.45	14.30	16.15	18.01	22.67	27.35
22	Single		6.08	8.24	10.41	12.61	14.81	17.02	19.24	21.47	27.06	32.67
	Multiple		6.28	8.48	10.70	12.93	15.17	17.41	19.67	21.92	27.59	33.28
24	Single			9.89	12.50	15.12	17.75	20.40	23.05	25.71	32.39	39.10
	Multiple			10.16	12.82	15.48	18.16	20.84	23.53	26.23	32.99	39.78
26	Single			11.70	14.77	17.86	20.97	24.09	27.21	30.35	38.22	46.12
	Multiple			12.00	15.13	18.27	21.42	24.58	27.75	30.92	38.89	46.88
28	Single			13.66	17.24	20.84	24.46	28.08	31.72	35.37	44.52	53.72
	Multiple			14.00	17.64	21.29	24.95	28.63	32.32	36.01	45.27	54.56
30	Single			15.78	19.90	24.05	28.21	32.39	36.58	40.78	51.32	61.90
	Multiple			16.15	20.34	24.54	28.76	32.99	37.23	41.48	52.14	62.82
35	Single				27.40	33.09	38.80	44.52	50.27	56.02	70.44	84.92
	Multiple				27.94	33.70	39.48	45.27	51.07	56.88	71.45	86.06
40	Single					43.59	51.09	58.60	66.14	73.69	92.62	111.61
	Multiple					44.32	51.90	59.50	67.10	74.73	93.83	112.97

$$\text{Volume} = [-0.08728 + 0.135420(\text{DRSQH})^{1/3} - 0.019587(\text{STEM})]^3$$ where: DRSQH = DRC squared times height; STEM = 1 if single, 0 if multiple.

Table 10.—Gross cubic foot volume for western juniper in the Great Basin States

DRC	Basal stems	Height (feet)													
		4	6	8	10	12	14	16	18	20	25	30	35	40	50
Inches		Cubic feet													
4	Single	0.06	0.09	0.13	0.18	0.22	0.26	0.31	0.36	0.40					
	Multiple	0.02	0.04	0.07	0.10	0.13	0.16	0.19	0.22	0.26					
6	Single	0.16	0.25	0.36	0.46	0.57	0.68	0.79	0.90	1.01	1.30	1.59			
	Multiple	0.08	0.15	0.22	0.30	0.39	0.47	0.56	0.65	0.74	0.97	1.21			
8	Single	0.31	0.50	0.69	0.89	1.09	1.29	1.50	1.71	1.92	2.44	2.98	3.52	4.07	
	Multiple	0.19	0.33	0.48	0.64	0.80	0.97	1.14	1.31	1.49	1.94	2.40	2.87	3.35	
10	Single	0.52	0.82	1.14	1.46	1.78	2.11	2.44	2.78	3.11	3.96	4.82	5.68	6.55	8.30
	Multiple	0.35	0.59	0.84	1.11	1.38	1.66	1.94	2.23	2.52	3.26	4.01	4.78	5.56	7.13
12	Single		1.24	1.71	2.18	2.66	3.14	3.63	4.12	4.61	5.86	7.11	8.38	9.65	12.20
	Multiple		0.93	1.31	1.71	2.12	2.54	2.97	3.40	3.83	4.93	6.06	7.20	8.35	10.68
14	Single		1.75	2.39	3.05	3.71	4.38	5.05	5.73	6.41	8.13	9.86	11.60	13.35	16.87
	Multiple		1.35	1.89	2.46	3.04	3.62	4.22	4.82	5.43	6.97	8.54	10.13	11.73	14.97
16	Single		2.34	3.20	4.07	4.94	5.83	6.72	7.62	8.52	10.78	13.06	15.36	17.66	22.30
	Multiple		1.85	2.59	3.35	4.12	4.91	5.71	6.51	7.32	9.38	11.47	13.57	15.70	20.00
18	Single		3.02	4.12	5.23	6.36	7.49	8.63	9.77	10.92	13.81	16.72	19.65	22.59	28.49
	Multiple		2.44	3.40	4.38	5.38	6.40	7.43	8.46	9.51	12.16	14.84	17.54	20.27	25.78
20	Single			5.16	6.55	7.95	9.36	10.78	12.20	13.63	17.23	20.84	24.48	28.13	35.46
	Multiple			4.32	5.56	6.82	8.09	9.38	10.68	11.99	15.30	18.65	22.03	25.44	32.32
22	Single			6.33	8.02	9.73	11.45	13.18	14.91	16.65	21.03	25.43	29.85	34.28	43.20
	Multiple			5.36	6.88	8.43	9.99	11.57	13.16	14.77	18.82	22.92	27.05	31.21	39.61
24	Single			7.62	9.65	11.69	13.75	15.82	17.89	19.98	25.21	30.47	35.75	41.06	51.71
	Multiple			6.51	8.35	10.21	12.10	14.00	15.92	17.85	22.71	27.63	32.59	37.59	47.65
26	Single				11.42	13.83	16.26	18.70	21.15	23.61	29.77	35.98	42.20	48.45	60.99
	Multiple				9.96	12.18	14.41	16.66	18.94	21.22	26.98	32.80	38.67	44.57	56.46
28	Single					16.16	18.99	21.83	24.68	27.54	34.73	41.94	49.19	56.46	71.05
	Multiple					14.32	16.93	19.57	22.22	24.89	31.63	38.42	45.27	52.15	66.02
30	Single						21.93	25.21	28.49	31.79	40.06	48.37	56.72	65.09	81.88
	Multiple						19.66	22.71	25.78	28.87	36.65	44.50	52.40	60.35	76.35
35	Single						30.23	34.73	39.23	43.75	55.09	66.48	77.91	89.37	112.36
	Multiple						27.41	31.63	35.87	40.13	50.86	61.67	72.56	83.50	105.51
40	Single						39.88	45.78	51.71	57.65	72.54	87.49	102.49	117.53	147.69
	Multiple						36.47	42.05	47.65	53.28	67.44	81.71	96.06	110.47	139.46
50	Single							72.54	81.88	91.24	114.71	138.25	161.86	185.52	232.95
	Multiple							67.44	76.35	85.29	107.76	130.38	153.11	175.92	221.77

Volume = $[-0.22048 + 0.125468(\text{DRSQH})^{1/3} + 0.100092(\text{STEM})]^3$ where: { DRSQH = DRC squared times height; STEM = 1 if single, 0 if multiple.

Table 11.—Gross cubic foot volume for either single-stem or multiple-stem Rocky Mountain juniper in the Colorado Plateau States and Idaho

DRC	Height (feet)											
	4	6	8	10	12	14	16	18	20	25	30	35
Inches	*Cubic feet*											
4	0.13	0.18	0.24	0.30	0.36	0.42	0.48	0.53	0.59			
6	0.27	0.40	0.53	0.66	0.79	0.92	1.05	1.17	1.30	1.62	1.94	
8	0.48	0.71	0.93	1.16	1.39	1.61	1.84	2.06	2.29	2.85	3.41	3.96
10	0.73	1.09	1.44	1.80	2.15	2.50	2.85	3.20	3.55	4.42	5.29	6.16
12	1.05	1.56	2.06	2.57	3.07	3.57	4.08	4.58	5.08	6.33	7.58	8.82
14	1.41	2.10	2.79	3.48	4.16	4.84	5.52	6.20	6.88	8.58	10.28	11.97
16	1.84	2.74	3.63	4.52	5.41	6.30	7.19	8.08	8.96	11.17	13.38	15.59
18	2.32	3.45	4.58	5.70	6.83	7.95	9.07	10.19	11.31	14.11	16.90	19.69
20		4.25	5.63	7.02	8.41	9.79	11.17	12.56	13.94	17.38	20.82	24.26
22		5.12	6.80	8.48	10.15	11.82	13.49	15.16	16.83	21.00	25.16	29.31
24		6.08	8.08	10.07	12.06	14.05	16.03	18.02	20.00	24.95	29.90	34.84
26		7.12	9.46	11.80	14.13	16.46	18.79	21.11	23.44	29.24	35.04	40.84
28		8.24	10.95	13.66	16.36	19.06	21.76	24.45	27.15	33.88	40.60	47.31
30			12.56	15.66	18.76	21.86	24.95	28.04	31.13	38.85	46.56	54.26
35				21.25	25.46	29.67	33.88	38.08	42.28	52.77	63.25	73.72
40					33.19	38.68	44.16	49.64	55.12	68.81	82.48	96.15

Volume = $[0.02434 + 0.119106(DRSQH)^{1/3}]^3$ where: DRSQH = DRC squared times height.

Table 12.—Gross cubic foot volume for oneseed juniper in eastern Colorado

DRC	Basal stems	Height (feet)										
		4	6	8	10	12	14	16	18	20	25	30
Inches		*Cubic feet*										
4	Single	0.06	0.10	0.15	0.20	0.25	0.30	0.36	0.41			
	Multiple	0.04	0.08	0.12	0.16	0.21	0.25	0.30	0.35			
6	Single	0.17	0.29	0.41	0.54	0.67	0.80	0.93	1.07	1.21		
	Multiple	0.14	0.24	0.35	0.47	0.58	0.70	0.83	0.95	1.08		
8	Single	0.36	0.58	0.81	1.05	1.30	1.55	1.80	2.06	2.31		
	Multiple	0.30	0.50	0.72	0.94	1.17	1.40	1.64	1.88	2.12		
10	Single	0.61	0.98	1.36	1.75	2.15	2.56	2.97	3.38	3.79		
	Multiple	0.53	0.87	1.23	1.59	1.97	2.35	2.74	3.13	3.52		
12	Single	0.93	1.49	2.06	2.64	3.23	3.83	4.43	5.04	5.65	7.20	
	Multiple	0.83	1.34	1.88	2.43	2.99	3.55	4.13	4.71	5.30	6.78	
14	Single	1.33	2.10	2.90	3.71	4.53	5.36	6.20	7.04	7.89	10.03	
	Multiple	1.20	1.92	2.67	3.44	4.23	5.02	5.82	6.63	7.45	9.51	
16	Single		2.83	3.89	4.97	6.06	7.16	8.27	9.39	10.51	13.34	16.20
	Multiple		2.61	3.62	4.65	5.69	6.75	7.81	8.89	9.97	12.71	15.48
18	Single		3.68	5.04	6.42	7.82	9.23	10.65	12.08	13.52	17.14	20.79
	Multiple		3.41	4.71	6.04	7.38	8.74	10.11	11.49	12.88	16.39	19.93
20	Single		4.63	6.34	8.07	9.81	11.57	13.34	15.13	16.91	21.42	25.96
	Multiple		4.32	5.95	7.61	9.30	11.00	12.71	14.44	16.17	20.55	24.97
22	Single			7.79	9.90	12.03	14.18	16.34	18.51	20.70	26.19	31.71
	Multiple			7.35	9.38	11.44	13.52	15.61	17.72	19.84	25.19	30.58
24	Single			9.39	11.93	14.48	17.06	19.65	22.25	24.87	31.44	38.06
	Multiple			8.89	11.34	13.81	16.31	18.83	21.36	23.90	30.31	36.77
26	Single			11.15	14.14	17.17	20.21	23.27	26.34	29.43	37.18	44.98
	Multiple			10.59	13.48	16.41	19.37	22.35	25.34	28.35	35.92	43.55
28	Single			13.06	16.56	20.08	23.63	27.20	30.78	34.37	43.41	52.50
	Multiple			12.43	15.82	19.25	22.70	26.17	29.67	33.18	42.01	50.91
30	Single				19.16	23.23	27.32	31.44	35.57	39.72	50.13	60.61
	Multiple				18.35	22.31	26.30	30.31	34.35	38.40	48.59	58.85
35	Single				26.53	32.13	37.76	43.41	49.09	54.78	69.08	83.45
	Multiple				25.52	30.98	36.48	42.01	47.57	53.14	67.17	81.28

Volume = $[-0.19321 + 0.136101(DRSQH)^{1/3} + 0.038187(STEM)]^3$ where: DRSQH = DRC squared times height; STEM = 1 if single, 0 if multiple.

Table 13.—Gross cubic foot volume for singleleaf pinyon in the Great Basin States

DRC	Basal stems	Height (feet) 4	6	8	10	12	14	16	18	20	25	30	35	40	50
Inches		*Cubic feet*													
4	Single	0.08	0.14	0.20	0.27	0.34	0.41	0.48	0.55	0.62					
	Multiple	0.09	0.15	0.22	0.29	0.36	0.43	0.51	0.58	0.66					
6	Single	0.24	0.39	0.55	0.72	0.89	1.06	1.24	1.42	1.60	2.06	2.52			
	Multiple	0.26	0.42	0.58	0.76	0.93	1.11	1.30	1.48	1.67	2.14	2.62			
8	Single	0.48	0.77	1.08	1.40	1.72	2.05	2.38	2.71	3.05	3.90	4.76	5.64	6.52	
	Multiple	0.51	0.82	1.13	1.46	1.79	2.13	2.47	2.81	3.15	4.03	4.91	5.80	6.70	
10	Single	0.81	1.30	1.80	2.31	2.84	3.37	3.90	4.44	4.98	6.35	7.74	9.14	10.55	13.39
	Multiple	0.86	1.36	1.88	2.40	2.94	3.48	4.03	4.58	5.13	6.53	7.94	9.36	10.79	13.68
12	Single	1.24	1.96	2.71	3.47	4.24	5.03	5.81	6.61	7.41	9.42	11.46	13.51	15.57	19.74
	Multiple	1.30	2.04	2.81	3.59	4.38	5.17	5.98	6.79	7.60	9.65	11.71	13.80	15.89	20.10
14	Single	1.76	2.77	3.81	4.87	5.95	7.03	8.12	9.22	10.32	13.11	15.92	18.75	21.60	27.33
	Multiple	1.83	2.87	3.94	5.02	6.11	7.21	8.32	9.44	10.56	13.39	16.24	19.11	21.99	27.79
16	Single		3.73	5.11	6.52	7.94	9.38	10.82	12.28	13.74	17.42	21.13	24.87	28.62	36.18
	Multiple		3.85	5.26	6.70	8.14	9.60	11.07	12.54	14.03	17.76	21.52	25.30	29.09	36.73
18	Single		4.83	6.61	8.41	10.23	12.07	13.92	15.78	17.65	22.35	27.09	31.86	36.65	46.29
	Multiple		4.97	6.79	8.62	10.47	12.34	14.21	16.10	17.99	22.75	27.55	32.37	37.21	46.94
20	Single			8.30	10.55	12.82	15.11	17.42	19.74	22.06	27.92	33.81	39.74	45.69	57.66
	Multiple			8.51	10.79	13.10	15.42	17.76	20.10	22.46	28.38	34.34	40.32	46.34	58.41
22	Single				12.94	15.71	18.51	21.32	24.14	26.98	34.11	41.28	48.50	55.74	70.30
	Multiple				13.22	16.03	18.86	21.70	24.56	27.43	34.64	41.89	49.17	56.48	71.16
24	Single				15.57	18.90	22.25	25.62	29.00	32.39	40.93	49.51	58.14	66.81	84.21
	Multiple				15.89	19.26	22.65	26.05	29.47	32.90	41.52	50.19	58.90	67.64	85.18
26	Single					22.39	26.34	30.32	34.31	38.31	48.38	58.50	68.68	78.89	99.40
	Multiple					22.79	26.79	30.81	34.84	38.89	49.05	59.26	69.52	79.81	100.48
28	Single					26.18	30.79	35.42	40.07	44.74	56.46	68.25	80.10	91.98	115.85
	Multiple					26.62	31.28	35.96	40.66	45.37	57.20	69.09	81.03	93.01	117.04
30	Single						35.59	40.93	46.29	51.67	65.18	78.76	92.41	106.09	133.58
	Multiple						36.13	41.52	46.94	52.37	66.00	79.69	93.43	107.22	134.89

Volume = $[-0.14240 + 0.148190(\mathrm{DRSQH})^{1/3} - 0.016712(\mathrm{STEM})]^3$ where: { DRSQH = DRC squared times height; STEM = 1 if single, 0 if multiple.

Table 14.—Gross cubic foot volume for pinyon in the Colorado Plateau States

DRC	Basal stems	Height (feet)													
		4	6	8	10	12	14	16	18	20	25	30	35	40	50
Inches		*Cubic feet*													
4	Single	0.09	0.16	0.23	0.30	0.37	0.45	0.52	0.60	0.68					
	Multiple	0.06	0.11	0.17	0.23	0.29	0.36	0.42	0.49	0.56					
6	Single	0.26	0.43	0.60	0.78	0.96	1.15	1.34	1.53	1.72	2.21	2.70			
	Multiple	0.20	0.34	0.49	0.65	0.81	0.98	1.15	1.32	1.50	1.94	2.40			
8	Single	0.52	0.84	1.17	1.51	1.85	2.20	2.55	2.90	3.26	4.17	5.08	6.00	6.94	
	Multiple	0.42	0.70	1.00	1.30	1.62	1.93	2.26	2.59	2.92	3.76	4.61	5.48	6.36	
10	Single	0.88	1.40	1.94	2.48	3.04	3.60	4.17	4.74	5.31	6.76	8.23	9.70	11.19	14.19
	Multiple	0.74	1.21	1.69	2.20	2.71	3.23	3.76	4.29	4.83	6.20	7.58	8.98	10.40	13.26
12	Single	1.34	2.11	2.90	3.71	4.53	5.36	6.19	7.03	7.87	10.00	12.15	14.31	16.49	20.87
	Multiple	1.15	1.85	2.59	3.34	4.10	4.87	5.66	6.45	7.25	9.27	11.31	13.37	15.46	19.66
14	Single		2.97	4.07	5.20	6.33	7.47	8.63	9.79	10.95	13.89	16.85	19.83	22.83	28.86
	Multiple		2.65	3.67	4.72	5.79	6.87	7.96	9.06	10.17	12.97	15.80	18.66	21.54	27.35
16	Single		3.98	5.45	6.94	8.44	9.95	11.48	13.01	14.55	18.43	22.34	26.27	30.22	38.16
	Multiple		3.59	4.96	6.36	7.78	9.22	10.67	12.13	13.60	17.32	21.07	24.86	28.67	36.35
18	Single		5.15	7.03	8.93	10.86	12.80	14.75	16.70	18.67	23.62	28.61	33.62	38.66	48.78
	Multiple		4.68	6.45	8.25	10.08	11.93	13.79	15.67	17.55	22.31	27.12	31.96	36.83	46.64
20	Single		6.47	8.82	11.19	13.59	16.00	18.43	20.87	23.32	29.47	35.67	41.90	48.15	60.72
	Multiple		5.92	8.14	10.40	12.68	14.99	17.32	19.66	22.02	27.95	33.94	39.97	46.03	58.25
22	Single			10.81	13.71	16.63	19.57	22.53	25.50	28.49	35.98	43.52	51.10	58.71	73.99
	Multiple			10.03	12.80	15.60	18.42	21.26	24.12	27.00	34.24	41.54	48.90	56.29	71.16
24	Single				16.49	19.99	23.51	27.06	30.61	34.18	43.15	52.17	61.23	70.32	88.58
	Multiple				15.46	18.82	22.20	25.62	29.05	32.50	41.18	49.93	58.74	67.59	85.39
26	Single					23.66	27.82	32.00	36.19	40.40	50.98	61.61	72.28	82.99	104.50
	Multiple					22.35	26.35	30.39	34.44	38.52	48.77	59.10	69.50	79.94	100.94
28	Single						32.49	37.36	42.25	47.15	59.46	71.84	84.26	96.73	121.75
	Multiple						30.87	35.58	40.31	45.06	57.02	69.07	81.18	93.34	117.80
30	Single							43.15	48.78	54.43	68.61	82.87	97.17	111.53	140.33
	Multiple							41.18	46.64	52.13	65.92	79.81	93.78	107.80	135.99

$$\text{Volume} = [-0.20296 + 0.150283(\text{DRSQH})^{1/3} + 0.054178(\text{STEM})]^3$$ where: DRSQH = DRC square times height; STEM = 1 if single, 0 if multiple.

Table 15.—Gross cubic foot volume for either single-stem or multiple-stem Gambel oak in Colorado

DRC	4	6	8	10	12	14	16	18	20	25	30	35
	Height (feet)											
Inches	*Cubic feet*											
4	0.09	0.15	0.21	0.28	0.35	0.42	0.49	0.56	0.64	0.82		
6	0.25	0.40	0.56	0.73	0.90	1.07	1.25	1.42	1.60	2.05	2.51	
8	0.49	0.79	1.09	1.40	1.72	2.04	2.37	2.70	3.03	3.86	4.70	5.55
10		1.31	1.80	2.31	2.82	3.34	3.86	4.39	4.92	6.25	7.60	8.96
12			2.70	3.44	4.20	4.96	5.73	6.50	7.27	9.23	11.20	13.19
14				4.81	5.85	6.91	7.97	9.03	10.11	12.80	15.52	18.26
16					7.79	9.19	10.59	12.00	13.41	16.97	20.56	24.16

Volume = $[-0.13600 + 0.145743(DRSQH)^{1/3}]^3$ where: DRSQH = DRC squared times height.

Table 16.—Gross cubic foot volume for either single-stem or multiple-stem bur oak in Wyoming and South Dakota

DRC	4	6	8	10	12	14	16	18	20	25	30	35	40	50
	Height (feet)													
Inches	*Cubic feet*													
4	0.17	0.23	0.29	0.35	0.40	0.46	0.51	0.57	0.62					
6	0.32	0.45	0.57	0.69	0.80	0.92	1.03	1.14	1.25	1.52	1.79			
8		0.72	0.93	1.13	1.32	1.52	1.71	1.90	2.09	2.55	3.01	3.47	3.92	
10		1.07	1.37	1.67	1.97	2.26	2.55	2.84	3.13	3.84	4.54	5.23	5.92	7.29
12			1.90	2.32	2.74	3.15	3.56	3.97	4.37	5.37	6.36	7.35	8.32	10.26
14			2.51	3.07	3.63	4.18	4.73	5.27	5.81	7.16	8.49	9.81	11.12	13.73
16				3.92	4.64	5.35	6.06	6.76	7.45	9.19	10.91	12.61	14.31	17.69
18					5.77	6.66	7.54	8.42	9.30	11.47	13.62	15.76	17.90	22.13

Volume = $[0.12853 + 0.105885(DRSQH)^{1/3}]^3$ where: DRSQH = DRC squared times height.

Table 17.—Gross cubic foot volume for mountain-mahogany in the central Rocky Mountain States

DRC	Basal stems	Height (feet) 4	6	8	10	12	14	16	18	20	25	30
Inches		*Cubic feet*										
4	Single	0.10	0.15	0.21	0.27	0.32	0.38	0.44	0.50	0.56		
	Multiple	0.05	0.09	0.13	0.18	0.22	0.27	0.32	0.36	0.41		
6	Single	0.24	0.37	0.50	0.63	0.77	0.90	1.04	1.18	1.32	1.66	2.01
	Multiple	0.16	0.26	0.36	0.47	0.58	0.70	0.81	0.93	1.05	1.35	1.65
8	Single	0.44	0.68	0.92	1.16	1.41	1.65	1.90	2.15	2.40	3.03	3.65
	Multiple	0.32	0.51	0.71	0.92	1.13	1.34	1.56	1.77	1.99	2.55	3.11
10	Single	0.71	1.09	1.47	1.86	2.24	2.63	3.03	3.42	3.81	4.80	5.79
	Multiple	0.53	0.85	1.18	1.52	1.86	2.20	2.55	2.90	3.25	4.15	5.05
12	Single	1.04	1.59	2.15	2.71	3.28	3.84	4.41	4.98	5.55	6.99	8.43
	Multiple	0.81	1.29	1.77	2.27	2.77	3.28	3.80	4.31	4.83	6.14	7.47
14	Single	1.44	2.20	2.96	3.73	4.51	5.28	6.06	6.84	7.63	9.59	11.56
	Multiple	1.15	1.81	2.49	3.18	3.88	4.59	5.30	6.01	6.73	8.54	10.37
16	Single		2.90	3.91	4.92	5.94	6.95	7.98	9.00	10.03	12.60	15.19
	Multiple		2.44	3.34	4.25	5.18	6.11	7.05	8.00	8.95	11.34	13.76
18	Single		3.70	4.98	6.27	7.56	8.86	10.16	11.46	12.76	16.03	19.31
	Multiple		3.15	4.31	5.49	6.67	7.87	9.07	10.28	11.50	14.55	17.63
20	Single		4.60	6.19	7.79	9.39	10.99	12.60	14.22	15.83	19.88	23.94
	Multiple		3.97	5.41	6.88	8.36	9.85	11.34	12.85	14.36	18.17	22.00
22	Single			7.53	9.47	11.41	13.36	15.32	17.27	19.23	24.14	29.07
	Multiple			6.64	8.43	10.24	12.05	13.88	15.71	17.56	22.19	26.85
24	Single				11.32	13.64	15.96	18.29	20.63	22.97	28.82	34.69
	Multiple				10.15	12.31	14.48	16.67	18.87	21.08	26.62	32.20

Volume $= [-0.13363 + 0.128222(\text{DRSQH})^{1/3} + 0.080208(\text{STEM})]^3$ where: DRSQH = DRC squared times height; STEM = 1 if single, 0 if multiple.

Table 18.—Gross cubic foot volume for either single-stem or multiple-stem hardwoods (willow, boxelder, maple, hawthorn, ash, locust, and cherry) in the central Rocky Mountain States.

DRC	Height (feet) 4	6	8	10	12	14	16	18	20	25	30	35	40	50
Inches	*Cubic feet*													
4	0.04	0.07	0.11	0.14	0.18	0.22	0.26	0.30	0.34	0.44	0.54			
6	0.13	0.21	0.30	0.39	0.48	0.57	0.67	0.77	0.87	1.12	1.37	1.63		
8		0.42	0.59	0.76	0.93	1.11	1.29	1.48	1.66	2.13	2.61	3.09	3.57	
10			0.98	1.26	1.55	1.84	2.13	2.43	2.73	3.48	4.24	5.02	5.79	7.36
12					2.32	2.75	3.18	3.62	4.06	5.17	6.29	7.43	8.56	10.86
14					3.26	3.85	4.45	5.06	5.67	7.20	8.76	10.32	11.89	15.06
16						5.15	5.94	6.75	7.55	9.58	11.63	13.70	15.77	19.95
18						6.63	7.65	8.68	9.71	12.31	14.93	17.56	20.21	25.54
20							9.58	10.86	12.15	15.38	18.64	21.92	25.21	31.83
22							11.74	13.30	14.86	18.80	22.77	26.76	30.77	38.83
24								15.98	17.86	22.58	27.33	32.10	36.89	46.53
26								18.91	21.13	26.70	32.30	37.93	43.58	54.94
28								22.10	24.68	31.17	37.69	44.25	50.83	64.05
30								25.54	28.52	35.99	43.51	51.07	58.65	73.87
35								35.24	39.33	49.59	59.91	70.27	80.66	101.52
40									51.91	65.40	78.96	92.57	106.21	133.60
50									82.36	103.65	125.03	146.47	167.97	211.10

Volume $= [-0.13822 + 0.121850(\text{DRSQH})^{1/3}]^3$ where: DRSQH = DRC squared times height.

*U.S. GOVERNMENT PRINTING OFFICE: 1985-0-576-040/10536

Chojnacky, David C. Pinyon-juniper volume equations for the central Rocky Mountain States. Research Paper INT-339. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985. 27 p.

Gross cubic foot volume equations are constructed for tree species in pinyon-juniper woodlands of Nevada, Idaho, Utah, Colorado, Wyoming, and South Dakota. Necessary variables for volume prediction are diameter at the root collar (DRC), total height, and a stem count. The equations are recommended for use in large State-wide woodland inventories.

KEYWORDS: woodland, cube root transformation, biweight regression, oak, mountain-mahogany

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