Converting Tree Diameter Measured at Root Collar to Diameter at Breast Height

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Pinyon pine (*Pinus edulis*), Utah juniper (*Junipers osteosperma*), and Gambel oak (*Quercus gambelii*) are dryland tree species often measured for diameter at the root collar (drc) near groundline (Figure 1). This measurement point is below most main stem branching typical of dryland species. The drc measurement standard has worked well for field inventory but presents a problem when results are compared to diameter data of trees measured at breast height dbh (1.37 m above groundline). Basal area calculation and other stand diameter comparisons, for example, are complicated when tree data include mixtures of trees measured at dbh and drc. Because drc is measured more than 1 m lower than dbh on a tree bole, drc measurements tend to yield larger numbers than dbh for the same tree. It may be preferable to convert all diameter data to a common measurement point for analyses involving basal area, diameter distributions, or data in diameter classes.

Herein we provide an equation for converting drc to dbh for three dryland species in western Colorado. We also discuss an application of equation use.

Trees were sampled at 17 locations along a convenient travel path in western Colorado (Figure 2). Trees were chosen to represent all sizes of pinyon pine, Utah juniper, and Gambel oak found in western Colorado. This was done by examining diameter distributions from data collected by the Forest Health Monitoring Program (FHM) in Colorado during 1992 and 1993 (USDA Forest Service 1997). FHM is a nationwide initiative to monitor ecological structure, trends, and health of the nation's forests.

From three to six trees for each species were selected from four size ranges corresponding to quartiles of the species' diameter distribution (1st to 25th, 26th to 50th, 51st to 75th, and 76th to 100th percentiles from FHM data). Because Utah juniper commonly branches at groundline, single-stem (at

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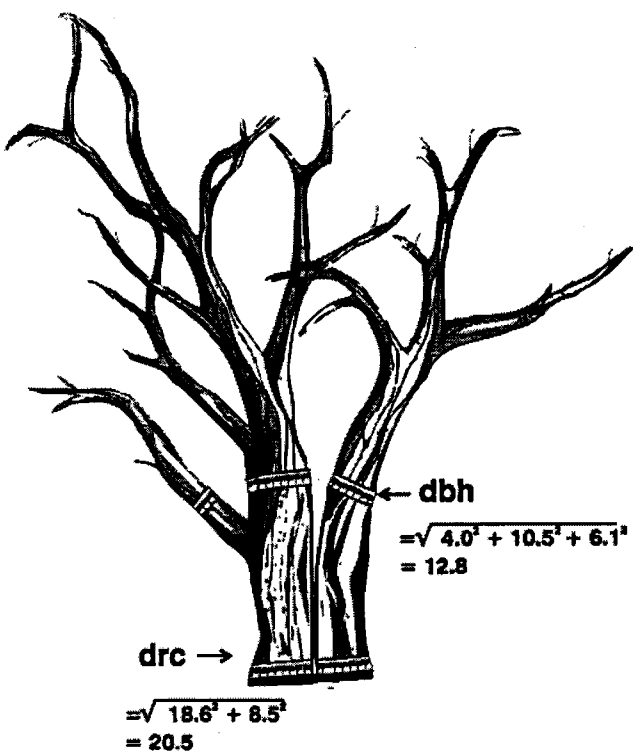

Figure 1. Diameter for multiple-stem juniper and other shrub-like trees is often measured at the root collar (drc) and then calculated from individual stem measurements. Likewise, diameter at breast height (dbh) can be calculated from individual stem measurements.

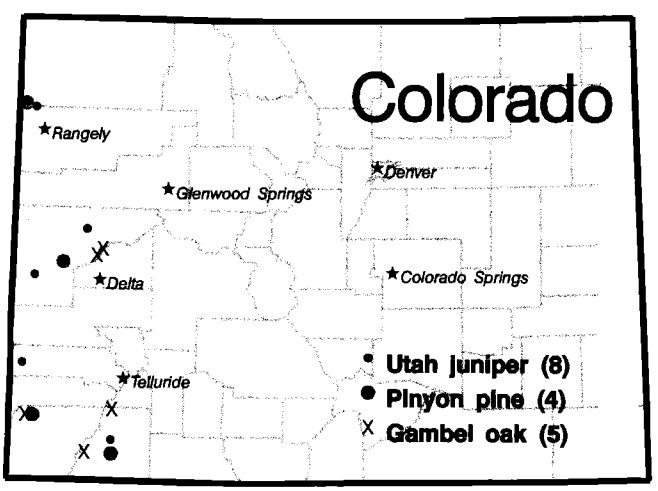

Figure 2. Diameter data were collected at 17 locations in western Colorado. A single species was measured at each location, but in some cases different species were sampled close together.

drc) and multiple-stem growth forms were sampled separately. Pinyon and Gambel oak were sampled without special regard for growth form, and some multiple-stem trees were included according to natural occurrence at sample sites.

A total of 224 trees were measured for diameter, total height, and crown diameter (Table 1). Trees ranged in size from 2.5 to more than 40 cm at drc. About half the juniper diameter classes had a single stem at drc, but more than half of these forked at dbh. Most pinyon pine and Gambel oak had a single stem at drc, but about half of the larger pinyon branched to multiple stems at dbh. Most Gambel oak maintained a single stem at both drc and dbh.

We calculated diameters drc and dbh (Figure 1) to normalize multiple- and single-stem trees in a similar metric (Meeuwig and Budy 1981, Batcheler 1985):

$$diameter = \sqrt{\sum_{i=1}^{n} d_i^2}$$

where

diameter = drc or dbh

n = number of stems at drc or dbh with diameter 2.5 cm or larger

d_i = diameter of all stems (live or dead) at drc or dbh that are 2.5 cm or larger

All live and dead tree stems that were at least 2.5 cm in diameter were included in drc and dbh calculations.

Data Analysis and Results

In a previous study for Gambel oak, a simple linear regression model ($dbh = \beta_0 + \beta_1 drc$) was used for converting drc to dbh (Chojnacky 1992). Graphic examination of this and other models showed that the simple linear regression model was adequate for the Colorado data.

Further analysis showed small differences in the drc to dbh relationship among species and between single- and multiple-stem trees. These differences were reasonably described by using a single model with dummy variables to account for dissimilarities. This was done because the 95% confidence intervals of mean predicted values for separate species equations mostly overlapped with one another, indicating little support for separate models.

Including height and crown diameter in the regression model slightly improved model fit but not enough to warrant their addition to the model. Also, height and crown variables are not widely measured so including them would limit model application in some cases.

Residual graphs were used to "fine tune" a final model fit from the data. The final model (Table 2) included intercept (β_0) and slope (β_1) parameters common for all species, and a parameter (β_2) for multiple- and single-stem trees also common to all species. Individual species effects were represented by parameters (β_3, β_4 for pinyon; β_5, β_6 for Gambel oak) that modified the common intercept and slope. If only the common parameters (β_0, β_1, β_2) are used, the model is unique to juniper.

For model validation, no similar pinyon-juniper data from other states were available, but there was a comparable conversion equation for Gambel oak in Arizona (Chojnacky 1992). Comparison of this model to Colorado data showed underprediction of dbh for trees 10 cm drc and larger. This comparison, however, was complicated by inconsistent diameter definitions. In the Arizona data, only the largest stem was measured at dbh, which means dbh was probably underestimated (by Colorado definition) for multiple-stem trees.

Inventory data for the 1.3 million ha Gila National Forest in New Mexico were used to examine the effect of the diameter conversion model in a regional assessment. As expected, data summary for pinyon-juniper and oak forest types showed reduced numbers for analyses by diameter classes. Surprisingly the ponderosa pine forest type (which includes some pinyon, juniper, and oak trees) showed 10 to 25% reductions in basal area when all tree diameters were considered at dbh (Figure 3). Similar analysis for pinyon-juniper and oak forest types exhibited 25 to 50% basal area reductions when converting from drc to dbh.

Table 1. Summary of 224 trees measured in western Colorado.

Species	Drc class (cm)	No. of trees (no.)	Mean drc (cm)	Single-stem at drc (%)	Mean stems at drc (no.)	Mean dbh (cm)	Single-stem at dbh (%)	Mean stems at dbh (no.)	Mean height	Mean crown diameter
									.....(m).....	
Utah juniper	2.5–10	23	5.9	61	1.5	1.0	35	0.7	1.4	1.0
	10–20	31	15.0	58	2.1	9.2	26	3.6	3.3	2.4
	20–40	27	29.4	59	1.9	24.1	15	5.9	4.4	3.9
	40+	25	53.9	48	2.5	49.3	24	6.0	6.2	5.8
Pinyon pine	2.5–10	13	6.4	85	1.2	2.1	69	0.8	1.9	1.3
	10–20	20	14.4	90	1.1	11.1	45	2.1	3.8	2.7
	20–40	18	28.3	100	1.0	25.1	50	1.9	5.9	4.8
	40+	9	53.1	100	1.0	49.1	56	1.8	7.9	7.7
Gambel oak	2.5–10	34	5.9	100	1.0	3.7	85	1.1	2.9	1.4
	10–20	20	14.8	100	1.0	12.4	90	1.2	6.4	2.9
	20–40	4	26.9	75	1.3	23.5	50	1.5	6.1	3.9

Table 2 Parameters and equation[1] to convert drc to dbh for pinyon pine, Utah juniper, and Gambel oak

Measurement	Parameter estimates							No. of	Fit statistics	
units	β_0	β_1	β_2	β_3	β_4	β_5	β_6	trees	R^2	*CV* (%)
English	–2.6843	1.0222	0.7433	0.7469	–0.0399	1.2244	–0.0689	224	0.98	13
Metric	–6.8180	1.0222	1.8879	1.8971	–0.0399	3.1100	–0.0689	224	0.98	13

[1] Conversion equation:

$$dbh = \beta_0 + \beta_1 drc + \beta_2 stm + \beta_3 Pied + \beta_4 drc_P + \beta_5 Quga + \beta_6 drc_Q$$

where

dbh = diameter at 1.3m above groundline of all live and dead stems 2.5 cm and larger (cm or in.)

drc = diameter at root collar above groundline of all live and dead stems 2.5 cm and larger (cm or in.)

$diameter = \sqrt{\sum_{i=1}^{n} d_i^2}$

n = number of live and dead stems at dbh or drc with diameter 2.5 cm or larger

d_i = stem diameter (cm or in.)

stm = 1 for trees with one stem (n = 1) at drc, 0 otherwise

Pied = 1 for pinyon pine species, 0 otherwise

drc_P = drc for pinyon pine species, 0 otherwise

Quga = 1 for Gambel oak species, 0 otherwise

drc_Q = drc for Gambel oak species, 0 otherwise

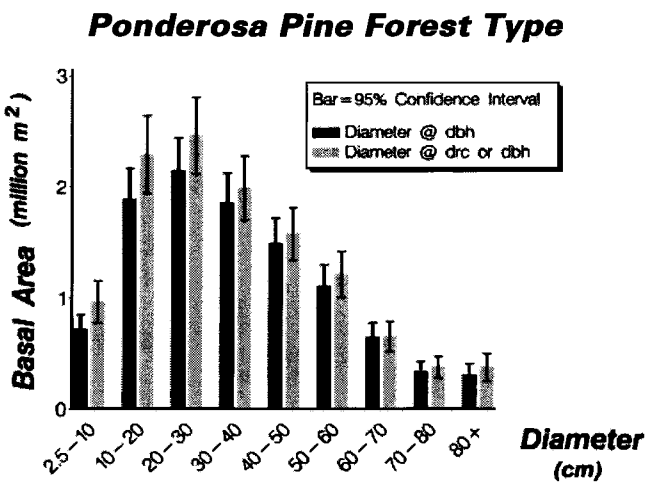

Figure 3. Basal area is reduced 10 to 25% in ponderosa pine forest type when diameters for pinyon-juniper and oak species within the type are converted to dbh. Data are from 1993–1994 inventory of the Gila National Forest, New Mexico.

The conversion equation provided a way to express diameter data at dbh for three species. Ecosystem assessments need such a common measurement point for all tree diameters, regardless of species, to properly evaluate relationships between species and diameter classes. We advise caution, however, in using this conversion equation outside of Colorado. Because data with similar measurement standards were unavailable for validation elsewhere, some test data should be collected and compared to the model to check its suitability for use in other states.

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