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ESTIMATING ABOVEGROUND BIOMASS OF SHRUBS AND YOUNG PONDEROSA AND LODGEPOLE PINES IN SOUTHCENTRAL OREGON

Darrell W. Ross
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ABSTRACT

Regression equations for estimating the aboveground biomass (ovendry weight) of individual plants of 10 shrub and 2 pine species were developed from data collected in southcentral Oregon. All include a single independent variable and were generated from logarithmically transformed data. Total aboveground biomass of each shrub species is predicted from canopy breadth or volume (length x width x height). Total aboveground and bole-only biomass of ponderosa and lodgepole pines (<3.5 m tall) are predicted from stem diameter, diameter squared times height, or total height. Equations for ponderosa pine were found to be site-specific for the three sampling locations. All of the regression equations are most appropriate for predicting plant biomass in the first 8 years after severe disturbance of forest sites in southcentral Oregon.

INTRODUCTION

In recent years, resource managers and researchers have increasingly needed reliable estimators of plant biomass (Gresham 1984, McClure 1984). The potential use of such material as an energy source has led to the inclusion of biomass estimates in forest inventories. These estimates may also be used to determine levels of competing vegetation in young conifer plantations (Ross et al. 1986), to evaluate wildlife habitat, and to assess fuel loading for fire management. Scientists use biomass estimates to study primary productivity, nutrient cycling, and the effects of alternative management practices. Unfortunately, because of the time and expense involved, regression equations that predict biomass have been developed for only a few species and geographic locations.

There are two general techniques for non-destructively estimating shrub biomass (Brown et al. 1982). One relies on the relationship between biomass and stem diameter, while the other relates biomass to canopy area or volume. Several researchers in Oregon and California have used canopy volume to estimate total aboveground biomass (dry weight) of shrubs. Bentley et al. (1970) found these two variables to be strongly correlated in four brush species in northern California. Wakimoto (1977) found that total aboveground biomass of seven chaparral shrub species in southern California was better estimated from canopy volumes than from linear measures of shrub size. Although Martin et al. (1981) found only a weak correlation between fuel content (biomass) and size of four shrub species in eastern Oregon and northern California, they attributed it to the limited range in size and to the variability in condition and shape of the sample shrubs.

Increased emphasis on artificial reforestation of inadequately stocked sites in southcentral Oregon during the past 20 years has resulted in many hectares of young even-aged pine plantations. No methods for estimating the biomass of pines in these plantations were available in the published literature until recently. From data collected in Montana and Idaho, Brown (1978) published equations for estimating biomass components of lodgepole (<u>Pinus contorta</u> Dougl. ex Loud.) and ponderosa (<u>P. ponderosa</u> Dougl. ex Laws.) pines. These data represented a wide range of site and stand conditions, tree sizes, and tree vigor. Gholz et al. (1979) used data from Colorado to develop equations for estimating biomass of lodgepole pine and data from Arizona to develop such equations for ponderosa pine. These equations were for lodgepole pines greater than 2.5 cm d.b.h. and ponderosa pines greater than 15.5 cm d.b.h. Cochran et al. (1984) published equations for estimating biomass components of even-aged second-growth ponderosa pines in central Oregon. The sample trees used to generate these equations ranged from 3.11 to 20.63 m in height. Standish et al. (1985) presented biomass equations for lodgepole and ponderosa pines in British Columbia, but the equations applied to trees 10 years old or older and greater than 3.3 cm d.b.h. and 2.0 m tall.

The equations presented here provide a method for estimating total aboveground biomass of 10 species of shrubs on the basis of canopy breadth or volume. We also provide equations for estimating total aboveground and bole-only biomass of two species of young pines (<3.5 m tall) on the basis of stem diameter, diameter squared times height, or total height.

SITE DESCRIPTIONS

All of the sample plants were collected during September 1983 at three sites on the Weyerhaeuser Company's Klamath Tree Farm in southcentral Oregon (Table 1). Ponderosa pine trees were collected at East Aspen, Swede Cabin, and Camp Nine. Lodgepole pine trees were collected only at Swede Cabin. All currant (Ribes spp.) and five of the gray rabbitbrush (Chrysothamnus naseosus [Pall.] Brit.) plants were collected at Swede Cabin; all of the other sample shrubs were collected at East Aspen: greenleaf manzanita, Arctostaphylos patula Greene; creeping hollygrape, Berberis repens Lindl.; snowbrush ceanothus, Ceanothus velutinus Dougl. ex Hook.; rabbitbrush goldenweed, Haplopappus bloomeri Gray; bitter cherry, Prunus emarginata (Dougl.) Walpers; antelope bitterbrush, Purshia tridentata (Pursh) D.C.; rose, Rosa spp.; snowberry, Symphoricarpos spp.

At each site, all of the ponderosa pines and shrubs were collected in 8-year-old plantations. Original site preparation of these plantations was by crawler tractors equipped with brushrakes that pushed the vegetation, logging debris, and some surface soil into windrows. The areas between windrows were then ripped by crawler tractors equipped with single-tooth rock rippers, and 2-0 bareroot ponderosa pine seedlings were planted in the rip rows at approximately 2.5-m x 2.5-m spacings. At Swede Cabin, the lodgepole pines were collected within 8-year-old research plots previously described by Ross (1985). These pines had been planted as 1-0 container (131-cm^3) seedlings at 1.2-m x 1.2-m spacings. All of the planted ponderosa and lodgepole pine seedlings had been produced by the Weyerhaeuser Company's Klamath Falls nursery and were grown from certified seed collected in the appropriate seed and elevational zones for each site.

Detailed climatic data for the three sites are not available, but within this geographic region the January mean minimum temperature ranges from -6° to -12°C and the July mean maximum temperature ranges from 29° to 31°C (Franklin and Dyrness 1973). The rain shadow created by the Cascade Range limits annual precipitation to between 25 and 50 cm. Precipitation is somewhat seasonal, with 55 to 75 percent occurring between October 1 and March 31.

TABLE 1.

CHARACTERISTICS OF THE THREE STUDY SITES.

Characteristic	East Aspen	Swede Cabin	Camp Nine
Location	NW 1/4 NE 1/4 Sec. 14, T. 38 S., R. 7 E., W.M.	SW 1/4 NW 1/4 Sec. 24, T. 36 S., R. 15 E., W.M.	NW 1/4 SE 1/4 Sec. 23, T. 32 S., R. 15 E., W.M.
Topography	Flat to gently undulating	Mid-slope bench	Flat to slightly concave
Slope (%)	0 – 10	0 – 12	0 – 10
Elevation (m)	1,370	1,610	1,950
Soil series[1]	Pokegama	Ze-eks	Ze-eks
Plant community[2]	Ponderosa pine/ bitterbrush/ needlegrass and Mixed conifer/ snowbrush-squawcarpet/ strawberry	White fir-ponderosa pine/snowberry/ starwort and White fir-ponderosa pine/ manzanita-Oregon grape	White fir-lodgepole pine/long-stolon sedge-needlegrass

[1] Soil series classifications follow Duncan and Steinbrenner (1975).

[2] Plant communities follow Hopkins (1979a) for East Aspen and Hopkins (1979b) for Swede Cabin and Camp Nine. East Aspen and Swede Cabin had characteristics of two plant communities and may be located at ecotones.

METHODS

Sample plants of each shrub and tree species were chosen to cover the size range encountered on research plots for which these equations were originally developed. The selected plants were generally free of severe competition, deformity, or damage. Since brushraking usually removes nearly all of the aboveground portion of plants, the shoots of the sample shrubs were, at most, 8 years old.

Prior to being harvested, each sample plant was measured for height and canopy width. Total shrub height was measured from the soil surface at the point of maximum canopy height, excluding any irregular, elongated branches. Total tree height was measured from the soil surface to the tip of the leader. Canopy breadth was measured along the widest axis (length) and perpendicular to that axis (width). Height and canopy breadth were measured to the nearest centimeter. Stem diameter was measured only on pine trees. Because the range in tree heights made it undesirable to measure diameters at a fixed height above the ground, stem diameter was measured at a height equivalent to 10 percent of the total height of the individual tree. Stem diameter was measured to the nearest millimeter.

After being measured, the plants were severed at the soil surface, cut into sections if necessary, placed in labeled plastic bags, and transported to the laboratory. They were then air-dried for several months before being dried in a forced-draft oven at 70°C for 48 hours. For the shrubs, the ovendry weight of the total aboveground biomass was determined to the nearest 0.1 g. For the pines, the ovendry weight of the bole-only (wood and bark) biomass was determined to the nearest 0.1 g.

Several variables were calculated for each plant from the measurements taken in the field. Mean canopy breadth was determined as the average of canopy length and width. Canopy volume was determined by using the measurements of height and canopy breadth in the equations for both an irregular cube (length x width x height) and a cylinder (π x mean radius squared x height). An indicator of bole volume for the pines was derived by multiplying stem diameter squared times height.

For each shrub species, a series of simple linear regressions were run: height, mean canopy breadth, and both of the measures of canopy volume were used as independent variables (X) to predict total aboveground biomass (Y). For each combination of tree species and site, another series of simple linear regressions were run: height, stem diameter, diameter squared times height, mean canopy breadth, and both of the measures of canopy volume were used as independent variables (X) to predict total aboveground and bole-only biomass (Y). Logarithmic transformation of all variables was necessary in every regression to correct for non-homogeneous variance and, in some cases, curvilinearity in the untransformed data. The form of the regression equation used was $\text{Ln}(Y) = a + b\,\text{Ln}(X)$. Although the biased estimate of the arithmetic mean associated with such regressions has been much discussed (Baskerville 1972, Crow and Laidly 1980, Flewelling and Pienaar 1981, Yandle and Wiant 1981), the problem does not seem major. Madgwick and Satoo (1975) demonstrated through simulated sampling that the variation in estimates from replicated samples is much greater than the inherent bias attributable to logarithmic regressions. More recently, Satoo and Madgwick (1982, pp. 23-26) compared several methods of estimating the biomass of forest stands and concluded that of all the options with double logarithmic regressions, the most consistent results are obtained with uncorrected estimates. After comparing corrected and uncorrected logarithmic regressions for ponderosa pine, Cochran et al. (1984) concluded that the logarithmic bias is not of practical importance with that species. Because of these findings, logarithmic bias was not corrected in our study.

Selection of the most suitable independent variable(s) for biomass predictions was based on estimates of relative error (E) (Whittaker and Woodwell 1968) and coefficients of determination (r^2), the latter of which are the most common measure of closeness of fit. Such coefficients may be inappropriate when sample selection is not random or when logarithmic transformations are used (Schreuder and Swank 1972). Whittaker and Woodwell (1968) recognized that coefficients of determination could be exaggerated for biomass regressions and suggested using the estimate of relative error as a measure of the relative accuracy of estimations. For a logarithmic regression, the estimate of relative error (E) is the antilog of the standard error of estimate. The estimate of relative error is analogous to the coefficient of variation. Consequently, as the value of E decreases, the reliability of a predicted Y value increases.

Since separate regression equations were developed for ponderosa pine at each of three sites, a general linear test (Neter et al. 1985; pp. 94-96, 345) was used to determine whether the regression equations were site-specific for this species. The F test statistic was used to compare the regressions for all three sites and each pair of sites at the 0.05 probability level.

RESULTS AND DISCUSSION

Shrubs

The E and r^2 values for regressions with each independent variable and shrub species are presented in Table 2. None of the independent variables tested resulted in the lowest E value for all species. However, because of their consistently low E values, high r^2 values, and ease of computation, mean canopy breadth and volume of cubic canopy were selected as the most appropriate independent variables for predicting shrub biomass. The coefficients and statistics in the biomass equations for each shrub species when these two variables are used as the independent variables are presented in Tables 3 and 4.

Alternative methods for estimating biomass of several of these shrub species have been published previously. Bentley et al. (1970) derived ratios of total aboveground biomass (dry weight) to canopy volume for greenleaf manzanita, snowbrush ceanothus, and bitter cherry in northern California. Those ratios as well as the equations in Table 4 were used to estimate the biomass of shrubs of the three species on a site being cleared in southcentral Oregon. For all three, the biomass estimates derived from the ratios were consistently 15 to 50 percent greater than those obtained with the regression equations in Table 4. At extremely low levels of shrub biomass, the estimates derived by ratios were as much as 200 percent greater than those derived by regression, although the absolute differences were small (0.1 versus 0.3 kg/ha). Possible reasons for agreement between the two sets of estimates were (1) similar field and analytical methods used in both studies, (2) similar age of sample plants (plants were less than 7 years old in the California study), (3) similar stand histories in the two studies, and (4) the proximity of the study sites. Variation between estimates derived by the two methods may be due to differences in climate and soil on the two sites. Such variation may also be due to the models employed or the range of canopy volumes sampled. Unfortunately, Bentley et al. (1970) did not specify the range of canopy volumes used to develop their ratios. Considering the variation in biomass estimates likely with repeated sampling in a given plant community, these two methods gave similar estimates over the range of plant sizes used to develop the regression equations.

TABLE 2.

SUMMARY OF ESTIMATES OF RELATIVE ERROR (E) AND COEFFICIENTS OF DETERMINATION (r^2) FOR REGRESSIONS WITH EACH INDEPENDENT VARIABLE AND SHRUB SPECIES.

Independent variable	Manzanita	Hollygrape	Ceanothus	Rabbitbrush	Goldenweed	Cherry	Bitterbrush	Currant	Rose	Snowberry
					E					
Total height	1.862	1.711	1.646	1.929	1.478	1.409	2.036	2.480	1.583	2.026
Mean canopy breadth	1.145	1.673	1.321	1.344	1.172	1.543	1.414	1.644	1.274	1.274
Volume of cubic canopy	1.208	1.382	1.236	1.160	1.200	1.366	1.428	1.770	1.128	1.243
Volume of cylindrical canopy	1.223	1.379	1.261	1.165	1.196	1.357	1.429	1.766	1.144	1.239
					r^2					
Total height	0.938	0.915	0.939	0.933	0.974	0.983	0.922	0.868	0.837	0.754
Mean canopy breadth	0.997	0.922	0.981	0.986	0.996	0.973	0.982	0.960	0.955	0.971
Volume of cubic canopy	0.994	0.969	0.989	0.996	0.994	0.986	0.980	0.948	0.989	0.977
Volume of cylindrical canopy	0.993	0.970	0.987	0.996	0.994	0.986	0.980	0.948	0.986	0.977

TABLE 3.

COEFFICIENTS AND STATISTICS IN BIOMASS EQUATIONS FOR 10 SPECIES OF SHRUBS WHEN MEAN CANOPY BREADTH IS USED AS THE INDEPENDENT VARIABLE.[1]

Species	X variable range	a	b	$s^2_{y \cdot x}$	n
	cm				
Manzanita	12 – 158	–5.4868	2.6925	0.018	10
Hollygrape	12 – 78	–5.4643	2.6939	0.265	10
Ceanothus	32 – 209	–6.9099	2.8452	0.078	10
Rabbitbrush	12 – 130	–6.3216	2.8426	0.088	10
Goldenweed	7 – 97	–5.9837	2.7479	0.025	10
Cherry	18 – 191	–7.2690	2.8934	0.188	11
Bitterbrush	22 – 166	–7.7562	3.1432	0.120	10
Currant	9 – 136	–5.9089	2.7811	0.247	10
Rose	8 – 44	–3.5932	1.8094	0.058	10
Snowberry	14 – 98	–5.6757	2.5432	0.059	12

[1] All of the regression equations were of the form Ln (Y) = a + b Ln (X), where Y = total aboveground biomass in grams and X = mean canopy breadth ((length + width)/2) in centimeters. $s^2_{y \cdot x}$ = variance associated with an equation (MSE), and n = sample size. E and r^2 values for each regression are presented in Table 2.

TABLE 4.

COEFFICIENTS AND STATISTICS IN BIOMASS EQUATIONS FOR 10 SPECIES OF SHRUBS WHEN VOLUME OF CUBIC CANOPY IS USED AS THE INDEPENDENT VARIABLE.[1]

Species	X variable range	a	b	$s^2_{y \cdot x}$	n
	cm^3				
Manzanita	1,560 – 2,103,904	–6.1575	0.9789	0.036	10
Hollygrape	1,152 – 362,496	–5.9299	0.9415	0.105	10
Ceanothus	21,924 – 3,588,480	–7.6750	1.0475	0.045	10
Rabbitbrush	1,170 – 1,787,520	–7.1034	1.0130	0.022	10
Goldenweed	490 – 546,720	–6.8245	1.0152	0.033	10
Cherry	11,760 – 6,551,454	–9.2957	1.1059	0.097	11
Bitterbrush	8,208 – 4,348,610	–7.9366	1.0837	0.127	10
Currant	616 – 2,307,888	–6.0076	0.9399	0.326	10
Rose	1,001 – 136,500	–4.3939	0.6480	0.014	10
Snowberry	4,485 – 590,426	–6.6729	0.9619	0.047	12

[1] All of the regression equations were of the form Ln (Y) = a + b Ln (X), where Y = total aboveground biomass in grams and X = canopy volume (length x width x height) in cubic centimeters. $s^2_{y \cdot x}$ = variance associated with an equation (MSE), and n = sample size. E and r^2 values for each regression are presented in Table 2.

Martin et al. (1981) published tables of shrub fuel loads (biomass) as a function of percentage of canopy cover for snowbrush ceanothus, greenleaf manzanita, and antelope bitterbrush. Their tables were based on data collected in eastern Oregon and northern California. For the snowbrush ceanothus and greenleaf manzanita in our study, total aboveground biomass estimated from the tables of Martin et al. ranged from 108 percent to as much as 3,000 percent greater than the estimates derived from the equations in Table 4. These large differences may be due to the ages of the sample plants in the two studies. Martin et al. (1981) sampled only sites with no recent history of severe disturbance, an indication that most of their sample shrubs were older than those in our study. If so, their tables may overestimate biomass of small, young plants. However, the estimates derived from the tables of Martin et al. for antelope bitterbrush ranged from 38 percent less to 52 percent more than those obtained with our regression equations.

Pines

The E and r^2 values for regressions with each dependent variable, independent variable, and site/pine species combination are presented in Table 5. For the regressions predicting total biomass, none of the independent variables was clearly superior to the others, although diameter squared times height consistently had one of the lowest E values. On the basis of E values, the latter was the best predictor of bole-only biomass for each site/pine species combination, and diameter was generally the next best predictor. Because of the ease of taking needed field measurements and the reliability of predictions, diameter and diameter squared times height were selected as the most appropriate independent variables for predicting pine biomass. However, since diameters were measured at an unusual position on the stem (10 percent of total height), equations with height as the independent variable are also reported for use when the required diameter measurements are unavailable.

F tests indicated that the regressions with diameter, diameter squared times height, or height as an independent variable were site-specific for ponderosa pine, with several exceptions. Among the regressions predicting total biomass and with diameter as the independent variable, those developed for Swede Cabin and Camp Nine were not significantly different. Among those predicting total or bole-only biomass and with height as the independent varible, the two developed for East Aspen and Camp Nine were not significantly different. Otherwise, the regressions for both total aboveground and bole-only biomass of ponderosa pine at each site were significantly different ($P<0.025$) from those for each of the other sites.

Other researchers have found biomass regressions to be site-specific for tree species. Koerper and Richardson (1980) found that such regressions for largetooth aspen (Populus grandidentata Michx.) in Michigan were significantly different for trees growing on sites of varying productivity. These results indicate that biomass equations developed from data collected at one site may not necessarily be applicable throughout the range of a species.

The coefficients and statistics in biomass equations for each site/pine species combination when diameter, diameter squared times height, and height are used as independent variables are presented in Tables 6, 7, and 8, respectively. Also included in these tables are coefficients and statistics when the data for ponderosa pine are pooled across all three sites. These equations are provided for general use on sites that do not match any of the three described here. The ratios of mean diameter to total height for each combination of pine species and site will enable the user to determine the applicability of the equations. The ratios are as follows:

Pine species and site	Mean diameter/ total height (cm/cm)
Ponderosa	
East Aspen	0.031
Swede Cabin	0.036
Camp Nine	0.038
Pooled data	0.035
Lodgepole	
Swede Cabin	0.026

It should be recalled that diameter was measured at 10 percent of total height.

TABLE 5.

SUMMARY OF ESTIMATES OF RELATIVE ERROR (E) AND COEFFICIENTS OF DETERMINATION (r^2) FOR REGRESSIONS WITH EACH DEPENDENT VARIABLE, INDEPENDENT VARIABLE, AND SITE/PINE SPECIES COMBINATION.

Dependent and independent variables	Site/pine species combination									
	East Aspen/ ponderosa	Swede Cabin/ ponderosa	Camp Nine/ ponderosa	Pooled data/ ponderosa[1]	Swede Cabin/ lodgepole	East Aspen/ ponderosa	Swede Cabin/ ponderosa	Camp Nine/ ponderosa	Pooled data/ ponderosa[1]	Swede Cabin/ lodgepole
	E					r^2				
Total biomass										
Total height	1.255	1.155	1.211	1.243	1.270	0.978	0.991	0.982	0.980	0.977
Stem diameter	1.105	1.196	1.256	1.264	1.150	0.996	0.986	0.975	0.976	0.992
Stem diameter squared x height	1.122	1.129	1.173	1.174	1.167	0.994	0.994	0.988	0.989	0.990
Mean canopy breadth	1.261	1.217	1.266	1.283	1.270	0.978	0.984	0.973	0.973	0.977
Volume of cubic canopy	1.149	1.144	1.165	1.196	1.188	0.992	0.992	0.989	0.986	0.988
Volume of cylindrical canopy	1.149	1.144	1.169	1.199	1.188	0.992	0.992	0.988	0.986	0.988
Bole–only biomass										
Total height	1.147	1.168	1.190	1.212	1.172	0.993	0.990	0.987	0.985	0.990
Stem diameter	1.133	1.168	1.214	1.264	1.111	0.994	0.990	0.984	0.978	0.996
Stem diameter squared x height	1.078	1.105	1.113	1.152	1.077	0.998	0.996	0.995	0.992	0.998
Mean canopy breadth	1.362	1.297	1.339	1.358	1.342	0.962	0.972	0.963	0.962	0.968
Volume of cubic canopy	1.197	1.213	1.216	1.243	1.207	0.987	0.985	0.983	0.981	0.987
Volume of cylindrical canopy	1.194	1.213	1.218	1.244	1.204	0.988	0.985	0.983	0.980	0.987

[1] Data pooled across all three sites.

TABLE 6.

COEFFICIENTS AND STATISTICS IN BIOMASS EQUATIONS FOR TWO PINE SPECIES AT THREE SITES WHEN STEM DIAMETER AT 10 PERCENT OF TOTAL HEIGHT IS USED AS THE INDEPENDENT VARIABLE.[1]

Pine species, site, and type of biomass computed (Y)	X variable range	a	b	$s^2_{y \cdot x}$	n
	mm				
Ponderosa					
East Aspen					
Total	10 - 82	-2.1865	2.4415	0.010	22
Bole only	10 - 82	-3.5451	2.5190	0.016	22
Swede Cabin					
Total	15 - 105	-3.7593	2.8119	0.032	18
Bole only	15 - 105	-5.0681	2.8821	0.024	18
Camp Nine					
Total	9 - 73	-3.1476	2.6154	0.052	20
Bole only	9 - 73	-4.8079	2.7676	0.038	20
Pooled data					
Total	9 - 105	-2.9251	2.6009	0.055	60
Bole only	9 - 105	-4.3922	2.7063	0.055	60
Lodgepole					
Swede Cabin					
Total	14 - 79	-4.1678	2.9870	0.020	15
Bole only	14 - 79	-5.4457	3.0896	0.011	15

[1] All of the regression equations were of the form Ln (Y) = a + b Ln (X), where Y = biomass in grams and X = stem diameter (taken at 10 percent of total height) in millimeters. $s^2_{y \cdot x}$ = variance associated with an equation (MSE), and n = sample size. E and r^2 values for each regression are presented in Table 5.

TABLE 7.

COEFFICIENTS AND STATISTICS IN BIOMASS EQUATIONS FOR TWO PINE SPECIES AT THREE SITES WHEN DIAMETER SQUARED TIMES HEIGHT IS USED AS THE INDEPENDENT VARIABLE.[1]

Pine species, site, and type of biomass computed (Y)	X variable range	a	b	$s^2_{y \cdot x}$	n
	cm³				
Ponderosa					
East Aspen					
Total	30.0 – 17 255.4	0.5146	0.8268	0.013	22
Bole only	30.0 – 17 255.4	–0.7754	0.8552	0.006	22
Swede Cabin					
Total	83.2 – 33 405.8	–0.1696	0.9104	0.015	18
Bole only	83.2 – 33 405.8	–1.3820	0.9323	0.010	18
Camp Nine					
Total	23.5 – 10 125.1	0.1115	0.8575	0.026	20
Bole only	23.5 – 10 125.1	–1.3541	0.9067	0.012	20
Pooled data					
Total	23.5 – 33 405.8	0.1495	0.8669	0.026	60
Bole only	23.5 – 33 405.8	–1.1976	0.9026	0.020	60
Lodgepole					
Swede Cabin					
Total	74.5 – 19 518.8	–0.3258	0.9203	0.024	15
Bole only	74.5 – 19 518.8	–1.4862	0.9537	0.006	15

[1] All of the regression equations were of the form $\mathrm{Ln}(Y) = a + b\,\mathrm{Ln}(X)$, where Y = biomass in grams and X = stem diameter (taken at 10 percent of total height) squared x height in cubic centimeters. $s^2_{y \cdot x}$ = variance associated with an equation (MSE), and n = sample size. E and r^2 values for each regression are presented in Table 5.

TABLE 8.

COEFFICIENTS AND STATISTICS IN BIOMASS EQUATIONS FOR TWO PINE SPECIES AT THREE SITES WHEN TOTAL HEIGHT IS USED AS THE INDEPENDENT VARIABLE.[1]

Pine species, site, and type of biomass computed (Y)	X variable range	a	b	$s^2_{y \cdot x}$	n
	cm				
Ponderosa					
East Aspen					
Total	30 - 263	-5.4488	2.5272	0.052	22
Bole only	30 - 263	-7.0145	2.6289	0.019	22
Swede Cabin					
Total	37 - 303	-5.2624	2.5409	0.021	18
Bole only	37 - 303	-6.5771	2.5980	0.024	18
Camp Nine					
Total	29 - 206	-4.8166	2.4173	0.036	20
Bole only	29 - 206	-6.5484	2.5525	0.030	20
Pooled data					
Total	29 - 303	-5.2552	2.5118	0.047	60
Bole only	29 - 303	-6.8408	2.6186	0.037	60
Lodgepole					
Swede Cabin					
Total	38 - 347	-5.0676	2.3717	0.057	15
Bole only	38 - 347	-6.4390	2.4655	0.025	15

[1] All of the regression equations were of the form Ln (Y) = a + b Ln (X), where Y = biomass in grams and X = total height. $s^2_{y \cdot x}$ = variance associated with an equation (MSE), and n = sample size. E and r^2 values for each regression are presented in Table 5.

CONCLUSION

The equations presented here will enable the user to estimate the biomass of certain plants in southcentral Oregon. However, applying them indiscriminately could result in misleading estimates. They should be restricted to plants similar in age, size, origin, condition, and habitat to those used to generate the equations. Consequently, they are most appropriate for estimating plant biomass in the first 8 years after severe disturbances such as logging, fire, or site preparation. For ponderosa pine, the user should select the equations for the site most nearly matching the plantation for which biomass estimates are desired.

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Regression equations for estimating the aboveground biomass (ovendry weight) of individual plants of 10 shrub and 2 pine species were developed from data collected in southcentral Oregon. All include a single independent variable and were generated from logarithmically transformed data. Total aboveground biomass of each shrub species is predicted from canopy breadth or volume (length x width x height). Total aboveground and bole-only biomass of ponderosa and lodgepole pines (<3.5 m tall) are predicted from stem diameter, diameter squared times height, or total height. Equations for ponderosa pine were found to be site-specific for the three sampling locations. All of the regression equations are most appropriate for predicting plant biomass in the first 8 years after severe disturbance of forest sites in southcentral Oregon.

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