Forestry Notes

BIOMASS REGRESSION EQUATIONS FOR COMMON TREE SEEDLINGS AND SHRUBS IN JASPER NATIONAL PARK, ALBERTA

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Equations which predict the oven-dry weight of foliage, roundwood in diameter size classes 0.0-0.5cm, 0.5-1.0cm, 1.0-3.0cm and total biomass are presented for lodgepole pine, Douglas-fir, white spruce, and aspen seedlings ($\leq$ 3m in ht.) and for Canadian buffalo-berry, ground juniper, Saskatoon-berry, white meadowsweet, and prickly rose. The logarithmic transformation of the allometric model with basal diameter as the independent variable produced the correlations; most r^2 ranged between 0.80 and 0.90. Also, equations which predict oven-dry weight from percent ground cover estimates were developed for common bearberry (r^2=0.84) and twin-flower (r^2=0.63). All sampling was done in the montane forest stands of Jasper National Park, Alberta, Canada.

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INTRODUCTION

Live plant biomass is "potential fuel" (Brown and Davis 1973) which may contribute to the total heat output, spread rate and resistance to control of a wildland fire. Shrub and tree seedling biomass is important because of the amount of organic material by weight and volume it contributes to the total fuel loading of a stand. In addition, these plants contribute to the vertical layering of the fuel bed. This third dimension directly affects the crowning potential of the stand because these shorter plants act as "ladder fuels" (Brown and Davis 1973). Also, the natural disposition of dead foliage, twigs and bark flakes are intercepted or collect on these standing plants, thus reducing the decaying process and creating a more continuous and well aerated fuel bed. This phenomenon is particularly important at the forest floor level where thick stands of common bearberry (*Arctostaphylos uva-ursi* (L.) Spreng.) or twin-flower (*Linnaea borealis* L. var. *americana* (Forbes) Hult. Woods.) are present (Alexander 1978).

Several authors have published regression equations which predict the oven-dry weight of standing live and dead biomass of understory shrubs and seedlings from easily obtained independent variables such as basal diameter, height, canopy or ground cover (percent) or diameter at breast height (dbh) (Brown 1976, Brown and Marsden 1976, Ohmann, et *al.* 1981, Agee 1983). But most of these relationships are for plant species not native to the study area or the data were obtained fromspecies growing on sites geographically distant from the study area which can contribute to differences in estimates for the same species (Harding and Grigal 1985). Additionally, most analogs were not developed to predict the weight of fuel components by the diameter size classes used by most forestry agencies in Canada.

Therefore, as part of a forest fuel quantification study (Delisle 1986), the relationships between various independent variables and oven-dry weight were developed for four species of tree seedlings ($\leq$ 3 m in height): lodgepole pine (*Pinus contorta* Loudon var. *latifolia* Engelm.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) white spruce (*Picea glauca* (Moench) Voss var. *albertiana* (S. Brown) Sarg.) and aspen (*Populus tremuloides* Michx.); five tall shrub species: Canadian buffalo-berry (*Shepherdia canadensis* (L.) Nutt.), ground juniper (*Juniperus communis* L.), Saskatoon (*Amelanchier alnifolia* Nutt.), white meadowsweet (*Spiraea lucida* Dougl.) and prickly rose (*Rosa acicularis* Lindl.); and two dwarf shrub species: common bearberry and twin-flower.[2]

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[2] Moss (1983) is the scientific reference for all common and scientific plant names used in this manuscript.

METHODS

Healthy shrubs and tree seedlings were collected during late July and August, 1985 from five different widely separated stands in the Montane Forest Region (Rowe 1972) of Jasper National Park, Alberta, Canada (52°6' and 53°2'N latitude and 117°5' and 118°4' W longitude). Information pertaining to the climate, geology and soils of the study-area are described by Holland and Coen (1982). The fire history and vegetation patterns of the area have been summarized by Tande (1979).

Tall shrubs and tree seedlings were systematically selected from within two-metre wide, randomly located and oriented belt transects such that two samples for every species were collected for every 0.10cm increase in basal diameter as measured at the root collar. The total number and distribution of samples by diameter size classes and the range in basal diameters varied as a function of the natural occurrence of the target species in the study area. Basal diameter (± 0.01cm), and stem length (± 0.1cm) were measured in the field for each stem. Oven-dry weights (± 0.1g) (24 h at 100°C) were determined for stem roundwood in the diameter size classes 0.0 - 0.5, 0.5 - 1.0, 1.0 - 3.0, 3.0 - 5.0, 5.0 - 7.0cm and for foliage. These roundwood diameter classes have been adopted by the Canadian Forestry Service and are used by them in fuel loading determination and fire behavior modelling.

The total (live and dead) oven-dry biomass (± 0.1g), height (± 0.5cm) and percent ground cover (± 1%) of common bearberry and twin-flower (n=210 and 230, respectively) were determined on 30- x 60-cm, randomly located plots widely distributed throughout the study area. Dwarf shrub plant tissue was not stratified into foliage and roundwood material due to the morphology of these two species. It was not practical to measure the basal diameter of these low growing shrubs due to the size and number of stems within a quadrant.

Both independent variables, singly or in appropriate combinations were regressed against total, foliage and roundwood biomass weights until the best predictive analogs were determined. Regression model selection was initially based on scatter diagrams of the raw data. Final model selection was based on high coefficient of determination (r^2), low standard errors of estimate (SEE), and highly significant ($p \leq .01$) F ratios (Draper and Smith 1981). All y-intercept (a) values listed for log-log equations were adjusted for logarithmic bias (Baskerville 1972) by solving the equation:

$$a = 10^{(a^1 + MSR/2)} \qquad [1]$$

where a^1 = the original intercept and MSR = mean square residual. Covariance analysis was used to determine if two or more independent variables were appropriate for predicting biomass weights.

RESULTS

Regression coefficients that best describe the relationship between the independent variables (basal stem diameter (d) and stem length (l) and the dependent variables of total above ground weight, foliage weight and roundwood weight, total and size class, are summarized in Table 1. The variable log (d) had the highest correlation with log weight (w) for all species and all the components tested. With the exception of the 0.5 - 1.0cm size class for lodgepole pine, all r^2 are generally high. Over 70% of the relationships account for over 80% of the variation in the data sets. All equations presented have highly significant F-ratios and all Y-intercepts and slopes were significant at the 99% level. Equations were not presented for the larger branchwood size classes (3.0 - 5.0cm) and (5.0 - 7.0cm) due to a shortage of data. Most stems within the range of basal diameters sampled do not produce biomass in these diameter classes.

The relationship between cover (percent) and weight (t/ha) for twin-flower was best modelled using the logarithmic transformation of the allometric equation while common bearberry (Figure 1) was best modelled using a

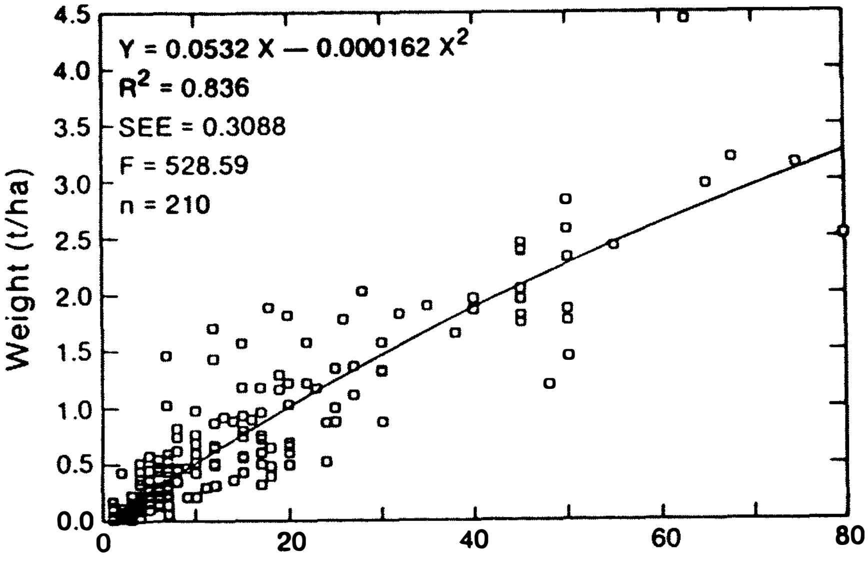

Figure 1. Data points and regression equation curve modelling the relationship between percent cover and oven-dry weight (t/ha) for common bearberry (*Arctostaphylos uva-ursi*).

Table 1. Regression equations for estimating ovendry weight components of various tree seedling and shrub species in the montane forest of Jasper National Parks of Alberta

Species (basal diameter range, cm)	Weight Component	n	r^2	SEE	Equation**
<u>Tree seedling</u>					
Lodgepole pine (0.27-5.64)	Total	85	0.984	0.1027	logY = 1.36 + 2.53 logd
	Foliage	85	0.948	0.1641	logY = 1.05 + 2.19 logd
	Wood	85	0.978	0.1371	logY = 1.03 + 2.84 logd
	0.0-0.5*	85	0.966	0.1307	logY = 0.65 + 2.18 logd
	0.5-1.0	76	0.463	0.3750	logY = 0.74 + 1.48 logd
	1.0-3.0	63	0.744	0.2713	logY = 0.80 + 2.75 logd
Douglas -fir (0.14-7.85)	Total	89	0.982	0.1222	logY = 1.39 + 2.43 logd
	Foliage	89	0.981	0.1157	logY = 1.12 + 2.24 logd
	Wood	89	0.981	0.1357	logY = 1.05 + 2.62 logd
	0.0-0.5	89	0.977	0.1245	logY = 0.83 + 2.17 logd
	0.5-1.0	79	0.848	0.2340	logY = 0.43 + 2.19 logd
	1.0-3.0	64	0.880	0.1843	logY = 0.57 + 2.81 logd
White spruce (0.19-5.64)	Total	86	0.984	0.1092	logY = 1.54 + 2.49 logd
	Foliage	86	0.973	0.1385	logY = 1.27 + 2.38 logd
	Wood	86	0.986	0.1099	logY = 1.19 + 2.63 logd
	0.0-0.5	86	0.974	0.1275	logY = 0.96 + 2.26 logd
	0.5-1.0	78	0.757	0.2577	logY = 0.61 + 1.83 logd
	1.0-3.0	64	0.799	0.2309	logY = 0.75 + 2.74 logd
Aspen (0.17-1.0)	Total	19	0.944	0.1447	logY = 1.17 + 2.29 logd
	Foliage	19	0.649	0.3138	logY = 0.31 + 1.65 logd
	Wood	19	0.966	0.1263	logY = 1.13 + 2.60 logd
	0.0-0.5	19	0.828	0.2157	logY = 0.72 + 1.83 logd
	0.5-1.0	9	0.743	0.1975	logY = 0.88 + 4.58 logd

Table 1. (continued)

Species (basal diameter range; cm)	Weight Component	n	r^2	SEE	Equation**
Tree seedling (continued)					
Tall shrubs					
Canadian buffalo-berry (0.19-3.19)	Total	59	0.971	0.1596	$\log Y = 1.58 + 2.77 \log d$
	Foliage	59	0.886	0.2427	$\log Y = 0.86 + 2.05 \log d$
	Wood	59	0.970	0.1715	$\log Y = 1.46 + 2.96 \log d$
	0.0-0.5	59	0.934	0.2049	$\log Y = 1.20 + 2.33 \log d$
	0.5-1.0	48	0.888	0.1745	$\log Y = 1.02 + 2.61 \log d$
	1.0-3.0	36	0.771	0.2511	$\log Y = 0.71 + 3.90 \log d$
Ground Juniper (0.08-3.0)	Total	44	0.975	0.1516	$\log Y = 1.79 + 2.43 \log d$
	Foliage	44	0.969	0.1599	$\log Y = 1.52 + 2.27 \log d$
	Wood	44	0.970	0.1786	$\log Y = 1.45 + 2.57 \log d$
	0.0-0.5	44	0.953	0.1893	$\log Y = 1.17 + 2.16 \log d$
	0.5-1.0	32	0.644	0.2790	$\log Y = 0.96 + 2.13 \log d$
	1.0-3.0	20	0.701	0.2164	$\log Y = 0.83 + 3.24 \log d$
Saskatoon (0.18-1.15)	Total	22	0.977	0.1239	$\log Y = 1.56 + 3.01 \log d$
	Foliage	22	0.901	0.1976	$\log Y = 0.71 + 2.21 \log d$
	Wood	22	0.981	0.1245	$\log Y = 1.50 + 3.35 \log d$
	0.0-0.5	22	0.961	0.1381	$\log Y = 1.05 + 2.53 \log d$
	0.5-1.0	12	0.770	0.2576	$\log Y = 1.35 + 4.63 \log d$
White meadowsweet (0.19-0.31)	Total	12	0.931	0.1134	$\log Y = 1.76 + 2.89 \log d$
	Foliage	12	0.805	0.1707	$\log Y = 0.98 + 2.40 \log d$
	Wood***	12	0.955	0.1002	$\log Y = 1.76 + 3.19 \log d$
Prickly rose (0.15-0.58)	Total	20	0.869	0.1863	$\log Y = 1.55 + 2.40 \log d$
	Foliage	20	0.570	0.3283	$\log Y = 0.93 + 1.89 \log d$
	Wood***	20	0.868	0.2115	$\log Y = 1.44 + 2.72 \log d$
Twin-flower	Total	230	0.626	0.3132	$\log Y = 1.79 + 1.05 \log c$
Common bearberry	Total	210	0.836	0.3088	$Y = 0.0532c - 0.0002c^2$

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* Roundwood diameter classes in cm.

** All y-intercepts have been corrected for logarithmic bias according to Baskerville (1972), d=basal diameter, c=percent cover.

***All branchwood was 0.0-0.5cm in diameter.

second degree polynomial equation. As with regression equations for tall shrubs and tree seedlings, the F-ratios and the slopes used in both dwarf shrub species were highly significant. A t-test conducted on the Y-intercept of the common bearberry regression equation was found to be non-significant hence the calculated intercept was rejected and the point of origin for the line representing this relationship was mathematically forced through (0,0).

DISCUSSION

We agree with the results of Brown (1976) that stem length could be used alone to predict component weights of tall shrubs and tree seedlings. But, we found as did Brown (1976) that correlation coefficients were not as high when stem length is used as the independent variable when compared to basal stem diameter. Further, we feel stem diameter is faster, easier and more accurate to measure under field conditions as compared to stem length.

Prediction equations were not developed for the two larger roundwood diameter size classes due to a lack of samples. Lodgepole pine, Douglas-fir and white spruce tree seedlings ($\leq$ 3m in ht.) only had 9, 16 and 14 observations, respectively in the 3.0 - 5.0cm size class and there were only 3 observations for fir roundwood within the 5.0-7.0cm size class. Therefore, we could not justify reporting the equations we found for these two large size classes not only because of a lack of data but because all models tested had poor distributions of residuals, high SEE, low r^2 and low F-values.

The percent of roundwood weight for individual size classes relative to the total roundwood weight was best modelled by the allometric equation ($Y=aX^b$) where $b \leq 0$ (Zar 1968). These results imitate those reported by Brown (1976) for the percentage of total air-dried stem material 0.0-0.5 cm in diameter relative to total roundwood weight. Hence, it was inappropriate to calculate an average value to represent the proportion of roundwood biomass distributed among size classes.

The high slope coefficients for the 0.5 - 1.0cm size class for aspen and Saskatoon (Table 1) as compared to the 0.0 - 0.5cm size class and foliage for these species suggests roundwood between 0.5 - 1.0cm in diameter accumulates faster than those other two components as basal diameter increases. This trend was not consistent among the other species. We believe this apparent anomoly is a result of animal predation. Small twigs and foliage of aspen and Saskatoon are known to be preferred wildlife foods. We also attribute the relatively low occurrence of aspen seedlings (n=19) and the narrow range in basal diameter (0.17 - 1.0 cm) encountered for this species to herbivory. There are a large number of free-ranging ungulates in Jasper National Park. Without predation, biomass distribution within aspen and Saskatoon would probably follow trends observed for Canadian buffalo-berry which, like white meadowsweet and prickly rose, are known to be rarely used by ungulates in the study area (Delisle 1986). The second degree polynomial equation is generally accepted to be the best model for explaining the relationship of plant cover to biomass for common bearberry (Brown and Marsden 1976, Alexander 1978). Yet, the differences in coefficients determined in the study as compared to those developed by Brown and Marsden, and Alexander are further justification for developing equations from data collected where the predictions are to be used.

The relatively poor (r^2=0.63) relationship of plant cover to plant weight for twin-flower is attributed to 5 observations where plant cover exceeds 30%. Although we cannot explain why plant weight appears to level off as plant cover over 30% increases, we had no justification for eliminating these observations from our analysis. We do not encourage the use of our equation to predict the weight of twin-flower when cover for this species exceeds 30%.

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