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Estimating Biomass of Shrubs and Forbs in Central Washington Douglas-Fir Stands

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Abstract

Understory plants in closed 70-year-old even-aged Douglas-fir stands in north central Washington were destructively sampled to determine the relationship of ground cover and height to dry weight. Weight of plant material can be estimated from the product of plant height and percent ground cover on 50- x 100-centimeter (cm) quadrats. Correlation coeffients for equations developed range from .70 to .96. The equations are best suited for calculating loadings in similar stands.

Keywords: Biomass, fuel loads, sampling methods, understory layer, woody plants, forbs, Douglas-fir, *Pseudotsuga menziesii.*

Introduction

Appraising the biomass of forest understory vegetation concerns both range and fire managers because the loading (weight per area) of shrubs and forbs determines, in part, the ability of a given area to support wildlife or propagate fire. In recent years, researchers have found that loading is well correlated with ground area covered by plants, plant height, and plant basal area (Brown and Marsden 1976, Alexander 1978, Evans and Jones 1958, Payne 1974). Calculating loading by this method is an improvement over the destructive sampling methods used previously.

In conjunction with a preliminary evaluation of the short-term effects on fire hazard of the western spruce budworm *(Choristoneura occidentalis)* (Martin and Olson 1979), relationships among plant ground cover, height, and dry weight were developed for seven important understory species in closed Douglas-fir *(Pseudotsuga menziesii)* stands of north central Washington.

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Methods

Plots for destructive sampling were located in four Douglas-fir stands in the Okanogan Highlands in north central Washington. The stands are an even-aged seral stage of the Douglas-fir/pinegrass habitat type *(Pseudotsuga menziesiil Calamagrostis rubescens).* Thirty 50- x 100-cm quadrats were randomly located within each stand. On each quadrat, height, percent cover, and loading were measured for each species. Cover was occularly estimated as a vertical projection of ground surface covered by the plant in percent classes, beginning with 0-2.5, and proceeding in 5-percent increments to the heaviest cover. Height of all plants was measured from the forest floor to the estimated average height of the plant in size classes of 5 centimeters after an initial class of 0-2.5. "Average height" of single-stem species was determined by taking an average of all plants of a species on the quadrat; "average height" of bushy shrub species was determined the same way but disregarding the occasional single sprigs that extended above the main bush. Loading was determined by clipping all vegetation at the forest floor and weighing, by species, to the nearest .1 gram (g) after oven drying for 48 hours at 70° C.

An additional observer independently estimated height and percent cover on each quadrat to determine the consistency in estimation.

Analysis

The independent variables percent ground cover and height were linearly regressed against loading, and a family of equations was developed to describe the relationships. Both linear and allometric equations were examined to determine the relationships. These were based on: height, cover, height times cover, height squared, cover squared, height squared times cover, and height times cover squared. Equations with the highest correlation coefficient (R^2) were selected as the model equations for each species individually and for all species combined.

Results

A total of 13 species occurred on 120 quadrats (table 1). The slope coefficients of the independent variables were significantly different from zero ($P<0.01$) for each species observed 20 or more times.

For most species, percent cover times height was the relationship most closely correlated to loading. Sidebells pyrola *(Pyrola secunda)* and pinegrass were most closely correlated to percent cover alone (table 2). The 13 species combined showed a close correlation between loading and cover times height (R^2 = 0.85).

There was an average difference of 1.5 percent between observations of ground cover made by two trained observers. Since the average cover value was 12.76 percent, the independent observation represents a 12-percent error. Stand characteristics are listed in table 3.

Summary

Percent ground cover times height, or percent ground cover alone, are well correlated to loading for the seven principal plant species occurring in the understory of Douglas-fir stands in north central Washington. Weight per area can be calculated with relative precision from equations developed in this study. This method provides a relatively simple, quick, and nondestructive method for estimating biomass or fuel loading.

Acknowledgement

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Table 1—Species and number of plots on which each occurred

Scientific name	No. plots	Common name
Pachistima myrsinites	77	Myrtle pachistima
Pyrola secunda	31	Sidebells pyrola
Vaccinium scoparium	26	Grouse whortleberry
Luzula spp.	22	Woodrush
Calamagrostis rubescens	34	Pinegrass
Thalictrum occidentale	21	Meadow rue
Goodyera oblongifolia	31	W. rattlesnake plaintain
Osmorrhiza chilensis	1	Sweetroot
Chimaphila umbellata	4	Prince's Pine
Viola spp.	5	Violet
Rosa spp.	1	Rose
Clematis columbiana	1	Columbian rock clematis
Spiraea betulifolia	3	Spirea

Table 2—Equations for estimating ovendry plant weight (y) (g/.5m^2) from percent plant ground cover (x_1) and plant height (x_2) (cm)

Species	n	Equation	R^2	Sy.x[1]
Pachistima	77	$y = 1.66075 + .06348\ x_1 x_2$	.95	9.83
Sidebells pyrola	31	$y = -.23194 + .50639\ x_1$	.86	2.21
Grouse whortleberry	26	$y = .87180 + .03988\ x_1 x_2$	.82	1.71
Woodrush	22	$y = .00709 + .06835\ x_1 x_2$	.90	0.83
Pinegrass	34	$y = .78009 + .25822\ x_1$	.70	0.03
Meadow rue	21	$y = .10045 + .00639\ x_1 x_2$	.96	0.39
Goodyera	31	$y = .39309 + .30382\ x_1 x_2$	.83	1.03
All species (13)	257	$y = -.62689 + .05778\ x_1 x_2$	.85	10.39

[1]Standard error of y given x.

Table 3—Stand characteristics by defoliation site (The plot means were averaged to get stand means except where sample size is indicated)[1]

Level of stand defoliation		Canopy coverage	Height of dominant and codominants	Crown height of dominants and codominants	Stems/ per hectare	Diameter of trees >12.7-cm (>5-in) breast height	Number of annual rings of dom. & codom.	Slope	Aspect	Elevation
		Percent	*Meters*	*Meters*		*Centimeters*		*Percent*		*Meters*
High	$\bar{x}$[2]	53.8	20.98	9.14	1,130	20.8	61.9	20	N	1 250
	s	.83	1.58	1.88	267	1.84	3.30	—	—	—
	n	—	11	11	—	—	11	—	—	—
Medium	$\bar{x}$	67.4	17.56	8.69	1,093	17.7	63.2	48	WNW	1 150
	s	1.01	5.22	3.42	83	1.05	5.22	—	—	—
	n	—	12	12	—	—	10	—	—	—
Low	$\bar{x}$	66.88	19.17	8.69	1,145	17.2	63.2	46	N	1 350
	s	1.70	1.16	1.94	220	1.11	5.61	—	—	—
	n	—	10	10	—	—	9	—	—	—
No	$\bar{x}$	66.03	19.71	15.47	1,085	19.1	62	44	N	1 350
	s	3.40	2.67	17.12	114	2.22	7.18	—	—	—
	n	—	12	12	—	—	13	—	—	—

[1]From Martin and Olson (1979).
[2] $\bar{x}$ = average
n = number
s = standard deviation.

Discussion

The equations developed in table 2 show a high degree of correlation between ovendry weight of forbs and percent ground cover times height. Variation unaccounted for by the independent variables is due to sampling variation, variation within classes of height and percent ground cover, and variation in ocular estimates.

Various researchers have shown that percent ground cover alone (Payne 1974) or percent ground cover times height (Crafts 1938) can be used to determine loadings of forbs and small shrubs at an acceptable level of precision. Equations developed for a species or group of species within one or two plant associations may not be acceptable for other plant associations because of variations in plant habit. Alexander (1978) and Brown and Marsden (1976) developed equations for species included in this study, but they found different correlations between cover, height, and weight. The equations developed in this study will work best in relatively closed Douglas-fir stands similar to those of north central Washington where data for this study were collected. Also, equations were developed from a limited range of values of the independent variables and should not be extrapolated much beyond the limits of the original data.

Application

Loading of understory vegetation can be calculated by determining percent ground cover and height of each plant within a 50- x 100-cm quadrat and using the appropriate equation. Height can be measured in classes of 0-2.5, 2.5-7.5, 7.5-12.5, ... cm (see Methods) and ground cover estimated as a vertical projection of ground surface covered in classes of 0-2.5, 2.5-7.5, 7.5-12.5, ... 92.5-97.5, 97.5-100 percent. The number of quadrats necessary for adequate estimates of plant height and cover depends on the precision required (Cochran 1963).

Tables 4 and 5 are prepared for easy estimation of herbage loading in English and metric units. The limits of the sampled data are outlined.

Table 4—Predicted herbage loading in tons per acre by ground cover and height[1]

	Ground cover (percent)									
Height	10	20	30	40	50	60	70	80	90	100
inches										
5	0.06	0.13	0.19	0.26	0.32	0.39	0.45	0.52	0.58	0.65
10	.13	.26	.39	.52	.65	.78	.91	1.04	1.17	1.30
15	.19	.39	.58	.78	.98	1.17	1.37	1.57	1.76	1.96
20	.26	.52	.78	1.04	1.30	1.57	1.83	2.09	2.35	2.61
25	.32	.65	.98	1.30	1.63	1.96	2.29	2.61	2.94	3.27
30	.39	.78	1.17	1.57	1.96	2.35	2.74	3.14	3.53	3.92

[1]Numbers within the lines are within the limits of data sampled.

Table 5—Predicted herbage loading in tonnes per hectare by ground cover and height[1]

	Ground cover (percent)									
Height	10	20	30	40	50	60	70	80	90	100
centimeters										
10	0.10	0.24	0.33	0.45	0.57	0.68	0.80	0.91	1.03	1.14
20	.24	.45	.68	.91	1.14	1.37	1.61	1.84	2.07	2.30
30	.33	.68	1.03	1.37	1.72	2.07	2.41	2.76	3.11	3.45
40	.45	.91	1.37	1.84	2.30	2.76	3.22	3.69	4.15	4.61
50	.57	1.14	1.72	2.30	2.88	3.45	4.03	4.61	5.19	5.77
60	.68	1.37	2.07	2.76	3.45	4.15	4.84	5.53	6.23	6.92
70	.80	1.61	2.41	3.22	4.03	4.84	5.65	6.46	7.27	8.08
80	.91	1.84	2.76	3.69	4.61	5.53	6.46	7.38	8.31	9.23

[1]Numbers within the lines are within limits of data sampled.