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BIOMASS ESTIMATION EQUATIONS FOR WETLAND TALL SHRUBS*

B. J. Connolly and D. F. Grigal**

ABSTRACT

Biomass estimation equations, using the allometric model, were developed for five species of wetland shrubs, Alnus rugosa, Betula pumila, Cornus stolonifera, Spiraea alba, and Salix spp. Equations were developed for total, leaf and stem mass of living shrubs, and for mass of standing dead shrubs. The equations were based on data collected in wetlands throughout Minnesota.

INTRODUCTION

The estimated 4.5 million ha. of wetlands in Minnesota have heretofore been considered to be unproductive and of little economic importance. Recent interest has developed in using for energy the biomass produced on these wetlands.

Tall shrubs such as alder (Alnus rugosa (DuRoi) Spreng.) and willow (Salix spp.) are common in wetlands (Jeglum et al. 1974). Although a number of studies have determined relationships between shrub biomass and more easily determined measures (Roussopoulos and Loomis 1979, Grigal and Ohmann 1977, Ohmann et al. 1976, Telfer 1969), nearly all data have been collected in uplands.

The objective of this study was to develop equations to estimate the biomass of major wetland tall shrub species in Minnesota, as part of a larger study of wetland shrubs (Connolly 1981).

The most common function used to relate woody-plant biomass to a predictor variable is the allometric or power function,

$$Y = AX^B$$

where X and Y are, respectively, predictor variable and estimated biomass; A and B are regression coefficients. Kittredge (1944) first used this function in its linear form,

$$\log Y = \log A + B \log X,$$

to estimate foliage from tree diameter. The linear, exponential, and hyperbolic functions have also been used to relate mass to a predictor variable. For example, Tilton and Bernard (1975) used the linear model, Brown (1965) the exponential, and Ogawa et al. (1965) the hyperbolic model.

The logarithmic transformation of the allometric function is often used to stabilize the increasing variance of mass commonly associated with an increase in plant size. However, underestimation of biomass can occur when the logarithmic estimates are converted back to the original units (Baskerville 1972). This error results from the largest values being squeezed onto the logarithmic scale, consequently having less leverage than smaller values (Beauchamp and Olson 1973). Finney (1941) and Meyer (1942) recognized this problem, and it has been discussed more recently by several others (Zar 1968; Crow 1971; Beauchamp and Olson 1973).

Two techniques are available to alleviate this bias. These are the use of a correction factor (Baskerville 1972) or the use of an iterative non-linear least squares method (Glass 1967). In the second case, best coefficients (A and B) of the equations are generated in the non-linear form from the original units of measurement, and thus a correction factor is not needed.

METHODS

Five taxonomic groups, believed to be the major wetland tall shrubs in Minnesota, were selected for this study. They are Alnus rugosa, Betula pumila L., Cornus stolonifera Michx., Spiraea alba DuRoi, and Salix spp. No attempt was made to identify species of willow when sampling, but two categories were distinguished based on leaf form: linear leaf and oblong leaf willow. Eleven species of willow were collected and identified within the sampling areas.

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**Research Assistant and Professor, Departments of Soil Science and Forest Resources, University of MN.

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A template, in 0.25-cm increments, was used to measure stem diameters at 15 cm above either ground level or the base of the shrub clump. The latter base often provided a more definite reference point than did the fluctuating wetland soil. In developing the estimation equations, the largest value of each size class was used. For example, shrubs with diameters from 0.50 to 0.75 cm fell in the 0.75 cm diameter class (Grigal and Ohmann 1977). Within each species, three sub-divisions were recognized: living, recently dead, and old dead. A recently dead shrub was defined as one that retained a majority of its branches and fine twigs, while an old dead shrub had no fine twigs and few or no branches on the stem.

During July and August 1978, shrubs were sampled in wetlands in sixteen counties throughout northern and eastern Minnesota. Samples were collected for each species over the range of diameter classes. Shrubs were severed at the base and bagged. The leaves were separated and components dried at 70°C until equilibrium. Each component was weighed to the nearest 0.1 g.

The allometric function was fitted to the data, predicting mass in grams (Y) with diameter in centimeters at 15 cm above the reference point (X). Both a linear (transformed data) and an interative non-linear technique (Nie et al. 1975) were used. Other functional relationships between X and Y were also explored.

RESULTS AND DISCUSSIONS

Almost 500 living and dead individuals of the five species were sampled, spanning a wide range of diameters and masses (Table 1). Plots of residuals verified that the allometric model was appropriate for the data when all species were considered although in some cases other models fit a particular species better. Such plots also indicated that for most species variances were relatively homogeneous; therefore, unweighted regression was used.

Regressions were compared, using the linearized form of the allometric function, for the following relationships: (1) recently dead versus old dead for each species, (2) oblong leaf versus linear leaf willows, (3) stem mass of live shrubs versus stem mass of dead shrubs. An F-test (Weisberg 1977) was used to test for significant differences between these regression lines.

Regressions of recently dead and old dead for each species were not significantly different (.05 level). These groups were combined to generate a single estimation equation for dead shrubs of each species. In comparing the regressions of oblong and linear leaf willows, only the regressions for leaf biomass were significantly different at the .05 level ($F=6.24$, $df=2,70$). Therefore, a single set of estimation equations was generated for the willows. The regressions for woody mass of live versus dead shrubs for alder, birch, and willow were significantly different at the .05 level. Therefore, different woody mass estimation equations were developed for live and dead shrubs for all species.

The data were then re-analyzed using the non-linear technique (Nie et al. 1975) to develop the final estimation equations. Because this technique was used, no corrections for bias arising from transformation were necessary.

Four biomass estimation equations were computed for each species: total mass; stem mass (live shrubs), stem mass (dead shrubs), and leaf mass (Table 2). Stem mass includes bark, buds, and fruits; the fruit component was always minor. Based on r^2 criteria and on plots of residuals, the equations generally fit the data well.

Comparisons of these results with published results for closely related species (Ohmann et al. 1976, Grigal and Ohmann 1977), using the same functional form, show differences in variability that are related to the range of data. As the range of diameters increases, the amount of explained variation decreases. In choosing the appropriate equation to use in biomass studies, it is therefore important to consider both the habitat and the range of data used to generate the equations. The equations presented here should be particularly appropriate in studies of wetland systems.

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Table 1. Dimensional data for developing shrub biomass estimation equations.

	Alnus rugosa live	Alnus rugosa dead	Betula pumila live	Betula pumila dead	C. stolonifera live	C. stolonifera dead	Salix spp. live	Salix spp. dead	Spiraea alba live	Spiraea alba dead
No. of observations	29	55	36	24	33	67	72	112	18	39
Independent variable										
Stem diameter class (cm)										
Mean	1.73	1.65	1.24	1.02	1.02	0.97	1.33	1.36	0.80	0.74
Standard error	0.18	0.13	0.11	0.14	0.09	0.06	0.10	0.08	0.08	0.05
Range	0.25-3.00		0.25-2.25		0.25-1.75		0.25-3.00		0.25-1.25	
Dependent variable										
Leaf mass (dry grams)										
Mean	20		8		12		19		6	
Standard error	3.9		1.7		2.6		2.8		1.5	
Maximum[1]	82		55		58		115		20	
Stem mass (dry grams)										
Mean	231	137	152	56	73	45	162	100	26	19
Standard error	47	21	27	21	17	7	30	14	6	3
Maximum	834	663	599	453	389	300	1006	687	78	76
Total mass (dry grams)										
Mean	251	137	160	56	85	45	172	100	32	19
Standard error	49	21	28	21	19	7	31	14	7	3
Maximum	874	663	617	453	448	300	1092	687	80	76

1/For all species the minimum mass of leaves was 0.1 g, wood was 0.2 to 0.3 g, and total was 0.2 to 0.4 g.

Table 2. Coefficients for wetland shrub biomass estimation equations of the form $Y=AX^B$, where Y is the oven-dry mass in grams and X is the diameter measured at 15 cm above the base rounded up to the nearest 0.25 cm.

	Alnus rugosa	Betula pumila	Cornus stolonifera	Salix spp.	Spiraea alba
Leaf mass					
A	13.540	6.265	7.992	13.194	8.013
B	0.845	1.106	2.440	1.224	1.444
r^2	.65	.52	.73	.64	.66
Sy.x (g)	17.78	9.21	10.13	16.82	5.45
Sy.x/$\bar{Y}$	0.87	1.16	0.84	0.90	0.89
No. of obs.	29	36	33	72	18
Stem mass, live shrubs[1]					
A	23.128	53.283	25.515	41.287	32.031
B	3.018	2.689	4.039	2.565	3.092
r^2	.96	.96	.89	.87	.95
Sy.x (g)	73.55	47.96	40.96	110.66	8.08
Sy.x/$\bar{Y}$	0.32	0.32	0.56	0.68	0.31
No. of obs.	29	36	33	72	18
Stem mass, dead shrubs[1]					
A	36.390	19.647	24.893	19.962	31.654
B	2.071	3.102	3.330	2.845	2.556
r^2	.81	.89	.79	.89	.89
Sy.x (g)	91.63	40.99	34.08	57.83	9.09
Sy.x/$\bar{Y}$	0.67	0.73	0.76	0.58	0.48
No. of obs.	55	24	67	112	39
Total mass, live shrubs					
A	33.722	59.777	32.791	60.153	40.932
B	2.712	2.579	3.806	2.202	2.658
r^2	.96	.96	.89	.83	.96
Sy.x (g)	75.47	49.41	46.72	132.13	9.62
Sy.x/$\bar{Y}$	0.30	0.31	0.55	0.77	0.30
No. of obs.	29	36	33	72	18

1/Stem mass includes bark, buds, and fruit.

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