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# BIOMASS ESTIMATION FOR SOME SHRUBS FROM NORTHEASTERN MINNESOTA

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ABSTRACT.--Biomass prediction equations were developed for 23 northeastern Minnesota shrub species. The allometric function was used to predict leaf, current annual woody twig, stem, and total woody biomass (dry grams), using stem diameter class estimated to the nearest 0.25 cm class at 15 cm above ground level as the independent variable.

OXFORD: 182.46:182.5(776). KEY WORDS: wildlife habitat, nonlinear regression analysis, allometric relations, dry weight, browse estimation.

A recent study (unpublished) to quantitatively describe a series of pine plantations in northeastern Minnesota as white-tailed deer and snowshoe hare habitat placed special emphasis on woody plants as potential browse. The descriptive information included shrub density and basal area. To estimate the browse represented by these data, equations were needed to determine the biomass of leaf and current annual woody-twig growth for each species. Reported here are the data collected and the resulting regression equations developed to produce the needed estimates. These equations should be useful to land managers, game managers, and other researchers who need to estimate biomass values for these species within the northern Lake States region.

For each of the major shrub species found in the plantations, stems spanning the size range were collected during the last half of August 1976. In the plantation study, shrub diameters had been determined to the nearest 0.25 cm at 15 cm above ground level. In sampling for the biomass estimation equations, we attempted to collect individuals from the lowest, highest, and middle size class for each species. Thus, if a species occurred in the study in size classes 1 (0 to 0.25 cm) through 7 (1.50 to 1.75 cm), we selected a minimum of three typical stems within each of three size classes spanning that range: for example, size class 1, 4 (0.75 to 1.00 cm), and 7. For shrubs with small diameters, such as Rosa blanda, we selected only stems within the lowest three size classes.

The stems were selected in the field, clipped at ground level, and taken to the laboratory where the leaves and current annual woody-twig growth were each separated from the remainder of the woody stem. Each component of each stem was bagged separately and dried at 70 C to constant weight. Each component was weighed to the nearest 0.01 gram immediately after removal from the oven.

Because of dry weather during the summer of 1976, some shrub stems had lost a portion of their leaves by late August. In those cases no leaf data were collected and the number of leaf biomass observations used in the leaf biomass regressions was reduced.

The independent variable, stem diameter size class; and each dependent variable-leaf,

current annual woody-twig, stem, and total woody biomass were summarized for each species (table 1).

The numerical value used for stem diameter was the upper end of the diameter class range. Stems 0.50 to 0.75 cm diameter, for example, were considered to be 0.75 cm diameter in the data summary.

In earlier work estimating biomass of five shrub species from northeastern Minnesota, we found that shrub biomass data conformed to the allometric function as well as or better than they did to alternative functional relations (Ohmann, Grigal, and Brander 1976)[1].

[1]*Ohmann, L. F., D. F. Grigal, and R. B. Brander. 1976. Biomass estimation for five shrubs from northeastern Minnesota. USDA For. Serv. Res. Pap. NC-133, 11 p. North Cent. For. Exp. Stn., St. Paul, MN 55108.*

Table 1.--*Dimensional data for 23 shrub spec*

| | *Acer rubrum* | *Acer spicatum* | *Alnus crispa* | *Alnus rugosa* | *Amelanchier* spp. | *Betula papyrifera* | *Cornus rugosa* | *Corylus cornuta* | *Lonicera canadensis* | *Lonicera hirsuta* | *Lonicera oblongifolia* | *Populu tremul* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Independent variable | | | | | | | | | | | | |
| Stem diameter class (cm) | | | | | | | | | | | | |
| Number of observations | 10 | 27 | 26 | 15 | 27 | 10 | 9 | 43 | 9 | 13 | 4 | 28 |
| Mean | 1.17 | 1.17 | 1.14 | .90 | 1.17 | 1.23 | 1.00 | 1.08 | .75 | .69 | .44 | 1.14 |
| Standard deviation | .51 | .52 | .52 | .53 | .52 | .55 | .43 | .53 | .43 | .27 | .13 | .53 |
| Standard error | .16 | .10 | .10 | .14 | .10 | .17 | .14 | .08 | .14 | .38 | .06 | .10 |
| Range | .50-1.75 | .50-1.75 | .50-1.75 | .50-1.75 | .50-1.75 | .50-1.75 | .50-1.50 | .50-1.75 | .25-1.25 | .25-1.00 | .25-.50 | .50-1.75 |
| Dependent variables | | | | | | | | | | | | |
| Leaf biomass (dry grams) | --- | | | | | | | | | | | |
| Number of observations | | 11 | 25 | 12 | 14 | 4 | 9 | 9 | 4 | 10 | 4 | 14 |
| Mean | | 4.33 | 9.51 | 6.04 | 8.62 | 3.11 | 11.41 | 15.46 | 2.33 | 2.34 | .54 | 6.77 |
| Standard deviation | | 11.79 | 9.18 | 8.64 | 6.75 | 4.33 | 10.35 | 15.75 | 1.52 | 2.86 | .35 | 9.81 |
| Standard error | | 3.56 | 1.84 | 2.49 | 1.80 | 2.16 | 3.45 | 5.25 | .76 | .91 | .18 | 2.62 |
| Range | | .01-39.44 | .07-27.00 | .15-29.08 | .05-19.95 | .62-9.57 | 1.32-27.17 | .11-36.21 | .16-3.68 | .18-9.29 | .08-.89 | .16-25.37 |
| Current annual twig (dry g) | | | | | | | | | | | | |
| Number of observations | 10 | 27 | 26 | 15 | 27 | 10 | 9 | 43 | 9 | 13 | 4 | 28 |
| Mean | 1.04 | 2.48 | 2.73 | 5.02 | 2.31 | 4.34 | 2.42 | 2.76 | .97 | 1.15 | .34 | 1.92 |
| Standard deviation | .72 | 2.49 | 3.31 | 6.31 | 2.52 | 6.85 | 2.03 | 2.92 | .92 | 1.36 | .36 | 1.80 |
| Standard error | .23 | .48 | .65 | 1.63 | .49 | 2.17 | .68 | .45 | .31 | .38 | .18 | .34 |
| Range | .10-2.39 | .12-10.83 | .18-12.67 | .36-19.80 | .01-8.26 | .51-23.23 | .25-5.58 | .12-10.30 | .06-2.50 | .06-4.62 | .05-.85 | .19-6.38 |
| Stem (dry grams) | | | | | | | | | | | | |
| Number of observations | 10 | 27 | 26 | 15 | 27 | 10 | 9 | 43 | 9 | 13 | 4 | 28 |
| Mean | 69.62 | 87.99 | 78.69 | 43.38 | 89.39 | 76.30 | 48.18 | 88.23 | 19.49 | 19.24 | 1.32 | 75.50 |
| Standard deviation | 73.00 | 87.81 | 77.76 | 63.38 | 84.50 | 81.78 | 50.14 | 102.96 | 19.69 | 22.14 | 1.00 | 73.51 |
| Standard error | 23.09 | 16.90 | 15.25 | 16.36 | 16.26 | 25.86 | 16.71 | 15.70 | 6.56 | 6.14 | .50 | 13.89 |
| Range | .81-207.11 | .34-345.90 | .34-268.00 | .36-171.40 | .48-258.72 | .51-247.69 | 1.30-131.57 | .57-380.75 | .27-52.52 | .20-65.20 | .20-2.62 | .42-234.69 |
| Total woody (dry grams) | | | | | | | | | | | | |
| Number of observations | 10 | 27 | 26 | 15 | 27 | 10 | 9 | 43 | 9 | 13 | 4 | 28 |
| Mean | 70.66 | 90.47 | 81.41 | 48.39 | 91.70 | 80.65 | 50.60 | 91.00 | 20.46 | 20.39 | 1.66 | 77.42 |
| Standard deviation | 73.50 | 89.10 | 78.74 | 68.93 | 86.07 | 83.38 | 52.12 | 105.66 | 20.54 | 23.02 | 1.13 | 74.79 |
| Standard error | 23.24 | 17.15 | 15.44 | 17.80 | 16.56 | 26.37 | 17.37 | 16.11 | 6.85 | 6.38 | .56 | 14.13 |
| Range | .94-208.19 | .66-351.90 | 1.05-271.00 | .72-181.37 | .96-259.83 | 1.02-251.62 | 1.55-137.15 | .60-391.05 | .54-54.86 | .27-66.98 | .25-2.94 | .84-239.04 |

Table 2.--*Regressions for estimation of biomass of 23 shrubs from*

| Regression factors on stem diameter class (cm) (X): | *Acer rubrum* | *Acer spicatum* | *Alnus crispa* | *Alnus rugosa* | *Amelanchier* spp. | *Betula papyrifera* | *Cornus rugosa* | *Corylus cornuta* | *Lonicera canadensis* | *Lonicera hirsuta* | *Lonicera oblongifolia* | *Populu tremul* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Leaf biomass (dry grams) (Y) | --- | | | | | | | | | | | |
| a | | 2.869 | 5.650 | 3.123 | 5.432 | 3.421 | 8.616 | 4.808 | 6.592 | 3.926 | 6.009 | 2.227 |
| b | | 3.669 | 2.222 | 3.071 | 2.008 | 1.838 | 2.541 | 3.571 | 2.681 | 1.163 | 3.115 | 4.258 |
| $R^2$ | | .608 | .748 | .718 | .875 | .990 | .940 | .991 | .901 | .242 | .749 | .963 |
| S y.x | | 7.788 | 4.706 | 4.815 | 2.486 | .524 | 2.701 | 1.568 | .586 | 2.644 | .217 | 1.956 |
| Probability of larger F value | | .005 | .005 | .005 | .005 | .010 | .005 | .005 | .100 | NS | NS | .005 |
| Current annual woody twig biomass (dry g) | | | | | | | | | | | | |
| a | 0.7676 | 2.174 | 2.349 | 4.122 | 1.510 | .588 | 1.813 | 1.196 | 1.325 | 1.974 | 3.756 | .89 |
| b | 1.4903 | 1.008 | 1.119 | 2.318 | 1.870 | 4.802 | 2.478 | 3.070 | 1.866 | 1.571 | 3.116 | 2.50 |
| $R^2$ | .724 | .260 | .196 | .815 | .426 | .282 | .946 | .774 | .801 | .281 | .284 | .43 |
| S y.x | .4021 | 2.186 | 3.028 | 2.815 | 1.947 | 6.155 | .506 | 1.406 | .440 | 1.208 | .373 | 1.38 |
| Probability of larger F value | .005 | .010 | .025 | .005 | .005 | NS | .005 | .005 | .005 | .100 | NS | .00 |
| Stem biomass (dry grams) | | | | | | | | | | | | |
| a | 21.0780 | 41.074 | 37.137 | 27.452 | 36.439 | 22.260 | 30.648 | 36.858 | 26.766 | 44.156 | 14.338 | 33.71 |
| b | 3.6892 | 2.706 | 2.772 | 3.122 | 2.995 | 3.452 | 3.184 | 3.272 | 2.180 | 3.578 | 3.082 | 2.87 |
| $R^2$ | .908 | .779 | .845 | .985 | .922 | .717 | .955 | .845 | .930 | .684 | .563 | .91 |
| S y.x | 23.5026 | 42.107 | 31.242 | 8.069 | 24.132 | 46.119 | 11.340 | 41.061 | 5.566 | 13.006 | .806 | 22.02 |
| Probability of larger F value | .005 | .005 | .005 | .005 | .005 | .005 | .005 | .005 | .005 | .010 | NS | .00 |
| Total woody biomass (dry grams) | | | | | | | | | | | | |
| a | 21.7300 | 43.660 | 39.684 | 31.328 | 37.909 | 22.865 | 32.421 | 38.031 | 28.090 | 46.002 | 18.093 | 34.50 |
| b | 3.6535 | 2.630 | 2.696 | 3.050 | 2.963 | 3.502 | 3.152 | 3.267 | 2.166 | 3.402 | 3.089 | 2.87 |
| $R^2$ | .911 | .778 | .855 | .991 | .924 | .764 | .957 | .847 | .931 | .678 | .695 | .91 |
| S y.x | 23.3043 | 42.776 | 30.571 | 6.824 | 24.158 | 42.982 | 11.590 | 41.881 | 5.759 | 13.635 | .762 | 22.31 |
| Probability of larger F value | .005 | .005 | .005 | .005 | .005 | .005 | .005 | .005 | .005 | .005 | NS | .00 |

[1]*All the woody growth was determined to be current annual. Stem and total woody biomass regressions were identical to current twig.*

In this study, then, the data for each species-variable combination were subjected to an iterative nonlinear, least squares regression analysis using the allometric relation

$$Y=aX^{b} \quad (1)$$

where Y is the biomass in grams dry weight of the dependent variable and X is the shrub diameter in cm at 15 cm above ground. The regressions were tested for significance using a standard F-test.

The resultant equation elements are presented in table 2.

*r 23 shrub species from northeastern Minnesota*

| *nicera* : *longifolia* | *Populus* : *tremuloides* | *Prunus* : *pensylvanica* | *Prunus* : *virginiana* | *Rhamnus* : *alnifolia* | *Ribes* : spp. | *Rosa* : *acicularis* | *Rosa* : *blanda* | *Rubus* : *parviflorus* | *Rubus* : *strigosus* | *Salix* : spp. | *Sorbus* : *americana* | *Viburnum* : *rafinesquianum* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 28 | 9 | 9 | 6 | 9 | 8 | 9 | 9 | 11 | 9 | 9 | 9 |
| .44 | 1.14 | 1.17 | .75 | 1.08 | .50 | .53 | .50 | .50 | .48 | 1.17 | 1.17 | 1.00 |
| .13 | .53 | .54 | .43 | .49 | .22 | .21 | .22 | .22 | .21 | .54 | .54 | .43 |
| .06 | .10 | .18 | .14 | .20 | .07 | .07 | .07 | .07 | .06 | .18 | .18 | .14 |
| .25- | .50- | .50- | .25- | .50- | .25- | .25- | .25- | .25- | .25- | .50- | .50- | .50- |
| .50 | 1.75 | 1.75 | 1.25 | 1.75 | .75 | .75 | .75 | .75 | .75 | 1.75 | 1.75 | 1.50 |
| 4 | 14 | 3 | 4 | 6 | 9 | 8 | 9 | 9 | 11 | 9 | 3 | 8 |
| .54 | 6.77 | .68 | 2.33 | 5.66 | .30 | 1.06 | 1.07 | 1.17 | .87 | 15.57 | .26 | 11.08 |
| .35 | 9.81 | .43 | 1.52 | 6.21 | .34 | .73 | 1.10 | 1.04 | 1.09 | 16.49 | .40 | 12.27 |
| .18 | 2.62 | .25 | .76 | 2.54 | .11 | .26 | .37 | .35 | .33 | 5.50 | .23 | 4.34 |
| .08- | .16- | .26- | .16- | .32- | .08- | .24- | .14- | .10- | .10- | .37- | .01- | .46- |
| .89 | 25.37 | 1.11 | 3.68 | 17.24 | 1.14 | 2.19 | 3.69 | 3.17 | 3.64 | 43.28 | .72 | 33.96 |
| 4 | 28 | 9 | 9 | 6 | 9 | 8 | 9 | 9 | 11 | 9 | 9 | 9 |
| .34 | 1.92 | 2.57 | .97 | 1.91 | .11 | .48 | .64 | 1.41 | .15 | 2.08 | 3.41 | 2.60 |
| .36 | 1.80 | 1.80 | .92 | 2.06 | .09 | .44 | .61 | 1.40 | .13 | 1.83 | 4.16 | 3.30 |
| .18 | .34 | .60 | .31 | .84 | .03 | .16 | .20 | .47 | .04 | .61 | 1.39 | 1.10 |
| .05- | .19- | .72- | .06- | .11- | .01- | .12- | .09- | .07- | .03- | .46- | .01- | .20- |
| .85 | 6.38 | 6.13 | 2.50 | 5.23 | .23 | 1.28 | 1.78 | 3.62 | .48 | 5.72 | 11.73 | 9.48 |
| 4 | 28 | 9 | 9 | 6 | 9 | 8 | 9 | | 11 | 9 | 9 | 9 |
| 1.32 | 75.50 | 97.74 | 75.67 | 51.91 | 2.59 | 2.54 | 3.32 | --- | 1.17 | 109.34 | 83.60 | 82.89 |
| 1.00 | 73.51 | 89.27 | 68.67 | 54.01 | 3.64 | 2.36 | 4.13 | | 1.61 | 131.46 | 99.72 | 95.10 |
| .50 | 13.89 | 29.76 | 22.89 | 22.05 | 1.21 | .83 | 1.38 | | .49 | 43.82 | 33.24 | 31.70 |
| .20- | .42- | 1.19- | .70- | 1.10- | .09- | .24- | .18- | | .08- | .64- | .30- | 1.45- |
| 2.62 | 234.69 | 247.12 | 185.79 | 139.82 | 10.69 | 6.56 | 10.42 | | 5.39 | 351.67 | 269.03 | 222.19 |
| 4 | 28 | 9 | 9 | 6 | 9 | 8 | 9 | 9 | 11 | 9 | 9 | 9 |
| 1.66 | 77.42 | 100.31 | 78.78 | 53.82 | 2.70 | 3.03 | 3.96 | 2.81 | 1.32 | 111.42 | 87.01 | 85.49 |
| 1.13 | 74.79 | 90.42 | 71.49 | 56.06 | 3.71 | 2.74 | 4.69 | 2.80 | 1.73 | 133.21 | 103.07 | 98.01 |
| .56 | 14.13 | 30.14 | 23.83 | 22.89 | 1.24 | .97 | 1.56 | .93 | .52 | 44.40 | 34.36 | 32.67 |
| .25- | .84- | 2.38- | .71- | 1.21- | .16- | .36- | .36- | .14- | .16- | 1.28- | .31- | 1.85- |
| 2.94 | 239.04 | 251.57 | 193.49 | 145.05 | 10.92 | 7.84 | 12.20 | 7.24 | 5.87 | 357.39 | 278.12 | 231.67 |

*23 shrubs from northeastern Minnesota (allometric relation $Y=aX^{b}$*

| *nicera* : *longifolia* | *Populus* : *tremuloides* | *Prunus* : *pensylvanica* | *Prunus* : *virginiana* | *Rhamnus* : *alnifolia* | *Ribes* : spp. | *Rosa* : *acicularis* | *Rosa* : *blanda* | *Rubus* : *parviflorus* | *Rubus* : *strigosus* | *Salix* : spp. | *Sorbus* : *americana* | *Viburnum* : *rafinesquianum* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6.009 | 2.227 | 4.947 | 7.953 | 2.009 | 1.513 | 3.286 | 4.160 | 4.595 | 7.081 | 4.514 | 2.885 | 8.526 |
| 3.115 | 4.258 | 2.836 | 1.954 | 3.835 | 3.023 | 2.004 | 2.302 | 2.376 | 3.871 | 3.692 | 3.454 | 3.007 |
| .749 | .963 | .000 | .900 | .881 | .549 | .879 | .597 | .720 | .748 | .894 | .000 | .951 |
| .217 | 1.956 | .601 | 3.522 | 2.394 | .245 | .275 | .745 | .586 | .577 | 5.735 | .560 | 2.925 |
| NS | .005 | NS | .005 | .010 | .025 | .005 | .025 | .005 | .005 | .005 | NS | .005 |
| 3.756 | .894 | 2.095 | 1.516 | 1.040 | .321 | 1.671 | 2.230 | 8.214 | .491 | .545 | .841 | 1.096 |
| 3.116 | 2.501 | 1.037 | 2.605 | 2.885 | 1.719 | 2.312 | 2.078 | 3.283 | 1.498 | 3.690 | 4.023 | 4.362 |
| .284 | .430 | .257 | .837 | .808 | .604 | .513 | .568 | .957 | .332 | .787 | .717 | .766 |
| .373 | 1.382 | 1.654 | 1.317 | 1.011 | .059 | .333 | .429 | .312 | .110 | .902 | 2.366 | 1.707 |
| NS | .005 | NS | .005 | .025 | .025 | .050 | .025 | .005 | .100 | .005 | .005 | .005 |
| 14.338 | 33.718 | 48.927 | 34.049 | 29.929 | 32.958 | 12.890 | 30.900 | ---[1] | 10.782 | 17.344 | 13.177 | 38.820 |
| 3.082 | 2.876 | 2.545 | 2.708 | 2.760 | 5.458 | 3.162 | 4.519 | | 4.111 | 4.939 | 4.393 | 4.125 |
| .563 | .914 | .950 | .856 | .874 | .776 | .908 | .873 | | .745 | .923 | .917 | .981 |
| .806 | 22.024 | 21.366 | 27.863 | 21.452 | 1.843 | .773 | 1.570 | | .857 | 39.009 | 30.800 | 14.172 |
| NS | .005 | .005 | .005 | .010 | .005 | .005 | .005 | | .005 | .005 | .005 | .005 |
| 18.093 | 34.502 | 49.916 | 35.575 | 30.971 | 32.001 | 14.527 | 31.182 | ---[1] | 11.519 | 17.815 | 13.982 | 39.921 |
| 3.089 | 2.874 | 2.547 | 2.704 | 2.764 | 5.256 | 3.042 | 4.074 | | 4.032 | 4.919 | 4.900 | 4.132 |
| .695 | .914 | .952 | .861 | .872 | .780 | .878 | .844 | | .734 | .923 | .922 | .981 |
| .762 | 22.316 | 21.233 | 28.520 | 22.456 | 1.861 | 1.035 | 1.979 | | .938 | 39.551 | 30.738 | 14.504 |
| NS | .005 | .005 | .005 | .010 | .005 | .005 | .005 | | .005 | .005 | .005 | .005 |

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