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Biomass Estimation for Black Spruce (Picea mariana (Mill.) B.S.P.) Trees*

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ABSTRACT

Two sets of biomass estimation equations were developed for several components of black spruce trees, one set using both diameter and height as independent variables and the other set using diameter alone. The data upon which the equations were based was collected from perched bogs in northern Minnesota. For most components, the standard error of the estimate was 10 to 25 percent of the mean of the dependent variable.

INTRODUCTION

Equations to estimate biomass of forest tree and undergrowth species are proliferating (Stanek and State, 1978). Equations derived from single locations are used for detailed ecosystem studies (Barney et. al., 1978; Crow, 1971). More general equations, using broader data bases, are used in surveys or extensive studies (Green and Grigal, 1978; Young et. al., 1980). In terms of generality, equations developed for limited geographic areas, such as counties, lie somewhere between (Ker, 1980).

The objectives of this study were to develop biomass estimation equations for black spruce (Picea mariana (Mill.) B.S.P.) for a specific study site.

METHODS

The study was conducted on the USDA Forest Service's Marcell Experimental Forest, in north central Minnesota. At Marcell, a detailed study of productivity and decomposition in perched bogs dominated by black spruce is being conducted. Perched bogs are wetlands that occupy small depressions in glacial moraines. Low hydraulic conductivities in their basal layers isolate them from regional ground water, and hence they receive the bulk of their nutrients via atmospheric contributions and recycling. The three-hectare spruce stand that we sampled was growing on a Loxley soil, a dysic, Typic Borosaprist. The stand was about 115 years old, with a site index of 8.2 m at 50 years, a stocking of 3725 trees ha^{-1}, and a basal area of 31 $m^2 ha^{-1}$.

Above-ground tree components were sampled in December, 1981. Twenty-four trees representing the range of diameters present on our study sites were felled on polyethylene sheets and cut into 1 m sections from base to tip. Branches were removed from each bole section, the section was weighed, and a cross-section disk was removed from its base. These disks were used to determine moisture content and proportion of bark. Each disk was considered separately, and therefore disks provided data for both the top and bottom of each bole section. Branches were separated into live and dead categories and weighed by 2-m bole sections. Subsamples of each kind of branch from each 2-m section were returned to the laboratory for determination of moisture content and foliage and cone mass. Below-ground biomass was determined for nine trees in summer 1981. Trees were felled and the below-ground portions were excavated. The smallest diameter of roots that were collected without loss due to breakage was approximately 3 mm. Root samples were weighed in the field, and subsamples in plastic bags were returned to the laboratory for the determination of moisture content. Data were converted from field weight to dry weight for all components, based on drying at 70° C.

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Relationships between dbh and mass of various components was evaluated using the allometric model,

$$Y = aD^b$$

where Y is mass in kg, and D is dbh in cm. The least squares fit of the model to the data was determined using a nonlinear estimation routine (Dixon and Brown, 1979). A modified allometric model,

$$Y = aD^bH^c,$$

where all variables are as above, but including total height (H) in m, was also fit to the data. Preliminary analyses indicated similar coefficients with or without weighting, probably because our samples were selected uniformly along the diameter range. We therefore report the unweighted results. Equations were computed for mass of total above-ground tree, of roots, bole with and without bark, live branch wood, dead branch wood, foliage, cones, and total crown (including live and dead branches).

RESULTS AND DISCUSSION

The 24 trees sampled for above-ground biomass represented the diameter (1.4 to 23.4 cm, $\overline{x}$ = 10.6 cm) and height (1.9 to 17.4 m, $\overline{x}$ = 10.8 m) range found on our study sites (Fig. 1). The data for root biomass was collected from a smaller range of tree sizes (dbh = 3.2 to 10.7 cm, $\overline{x}$ = 6.4 cm).

As is commonly reported in the literature, total above-ground biomass conformed well to the allometric relationship with diameter (R^2 = 0.99), while some of the more variable components, such as foliage and cones, conformed less well (Table 1). Addition of height as an independent variable did little to reduce the standard error of estimate (Table 1, Table 2). The sum of the mass of component parts, based on individual equations for each part, is not exactly equal to total mass based on a single equation. This occurs because the nonlinear estimation routines do not provide exact solutions, but converge iteratively. Differences between the two estimates of mass are small; a few percent or less.

These equations should be applicable to mature black spruce growing in relatively dense stands in the northern Lake States. They should be used cautiously in specific studies, and ideally with some form of testing.

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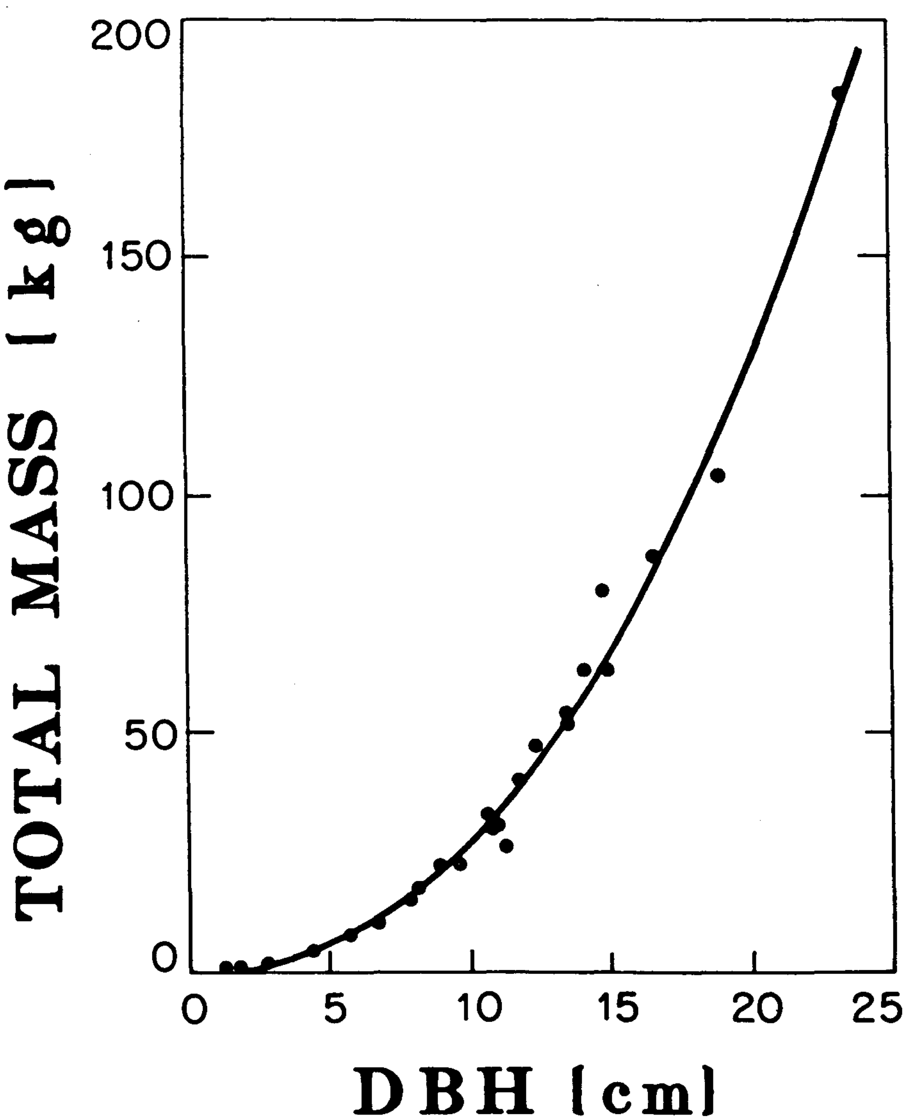

Fig. 1. Total above-ground biomass (kg) versus dbh (cm) for the data and the corresponding regression line; mass = $0.153\ (\text{dbh})^{2.248}$.

TABLE 1. Coefficients for generalized biomass estimation equations for black spruce of the form $Y = aD^b$, where Y is ovendry mass in kilograms and D is dbh in centimeters.

Component	a	b	R^2	n	$S_{y.x}$[1]	$S_{y.x}/\bar{Y}$
Bole bark	.0438	1.822	0.93	24	0.914	0.242
Bole wood	.0888	2.321	0.98	24	4.555	0.155
Total bole	.1183	2.260	0.98	24	4.288	0.129
Cones	.0003	2.526	0.40	15	0.234	0.981
Foliage	.0610	1.411	0.77	24	0.678	0.371
Live branches	.0251	2.000	0.91	24	0.977	0.276
Dead branches	.0004	3.324	0.93	24	0.976	0.423
Total crown	.0238	2.315	0.95	24	1.863	0.238
Roots	.0950	1.987	0.95	9	0.718	0.169
Total above-ground	.1530	2.248	0.99	24	4.631	0.112

[1]Values are given in kilograms

Table 2. Coefficients for generalized biomass estimation equations for black spruce of the form $Y = aD^bH^c$, where Y is ovendry mass in kilograms, D is dbh in centimeters, and H is height in meters.

Component	a	b	c	R^2	n	$S_{y.x}$[1]	$S_{y.x}/\bar{Y}$
Bole bark	.0036	0.868	1.902	0.96	24	0.698	0.185
Bole wood	.0545	2.153	0.361	0.98	24	4.680	0.159
Total bole	.0576	1.992	0.543	0.98	24	4.080	0.123
Cones	.000006	6.499	−2.730	0.01	15	0.375	1.572
Foliage	.0268	1.002	0.726	0.77	24	0.680	0.373
Live branches	.0509	2.287	−0.560	0.91	24	0.983	0.277
Dead branches	.000009	2.467	2.320	0.93	24	0.969	0.420
Total crown	.0298	2.394	−0.165	0.94	24	1.905	0.243
Roots	.0088	3.740	−0.789	0.95	9	0.732	0.172
Total above-ground	.0862	2.040	0.426	0.99	24	4.466	0.108

[1]Values are given in kilograms.

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