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naturels de la forêt expérimentale de Petawawa*

Abstract

Aboveground ovendry masses of tree components and total trees for six hardwood species from natural stands were studied at the Petawawa National Forestry Institute's research forest in eastern Ontario. Eighteen sample plots were measured, and 197 sample trees 0.1 cm and greater in diameter at breast height outside bark were cut, weighed, and processed for their ovendry mass. Wood densities were also taken. Regression equations based on tree variables of diameter at breast height outside bark and height were developed for the ovendry mass of forest-grown individual trees by components. Relationships among various parameters of tree mass were also established. In addition, average ovendry mass of stands was calculated. Results were summarized in tables.

Résumé

La masse anhydre de la portion épigée des différentes parties et de la totalité des arbres appartenant à six espèces de feuillus a été mesurée dans des peuplements naturels de la forêt expérimentale de l'Institut forestier national de Petawawa, dans l'est de l'Ontario. On a divisé le terrain en dix-huit parcelles, et on a coupé et pesé avant et après séchage à l'étuve 197 arbres présentant un diamètre à hauteur de poitrine sur écorce égal ou supérieur à 0,1 cm. On a aussi mesuré la masse volumique du bois. On a élaboré des équations de regression donnant la masse anhydre d'arbres individuels cultivés en forêt, selon les différentes parties et en fonction du diamètre à hauteur de poitrine sur écorce et de la taille. On a aussi établi des relations entre les divers paramètres de masse des arbres. En outre, on a calculé la valeur moyenne de la masse anhydre des peuplements. Les résultats ont été résumés dans des tableaux.

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ABOVEGROUND-MASS EQUATIONS FOR SIX HARDWOOD SPECIES FROM NATURAL STANDS OF THE RESEARCH FOREST AT PETAWAWA

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Introduction

Because of the predicted shortage of fuel energy, *forest biomass* is destined to become an important source of Canada's energy supply. Forest biomass is the quantity of living matter in the forest ecosystem expressed in terms of its mass.* In this paper the term is confined to the aboveground portions of trees and shrubs. Within this context, it can also be defined as transformed solar energy in the form of vegetational substances. Forest biomass being a forest product, the present capacity and growth of the forest in terms of mass must be known in order to provide for its long-term management. A first step towards evaluation is to determine the biomass values of single trees of various species, both commercial and noncommercial. The purpose of this study was to contribute to present information by deriving mass equations for some hardwood species. More precisely, the objectives were (1) to derive prediction equations for aboveground ovendry mass of forest-grown individual trees by tree components and (2) to calculate average aboveground ovendry mass of natural stands of mixed hardwoods. The following tree species from eastern Ontario were studied: trembling aspen (*Populus tremuloides* Michx.), white birch (*Betula papyrifera* Marsh.), sugar maple (*Acer saccharum* Marsh.), red maple (*Acer rubrum* L.), red oak (*Quercus rubra* L.), and ironwood (*Ostrya virginiana* [Mill.] K. Koch).

Study area

The research forest of the Petawawa National Forestry Institute at Chalk River, Ontario—latitude 45°58′N, longitude 77°32′W—provided the study area. There, the hardwood stands of mixed tolerant and intolerant species from which the samples were taken are naturally established, mature, uneven-aged, fully stocked, and healthy, growing on shallow glacial till soils. Site quality is variable—from dry to fresh, by Hill's classification (Hills and Pierpoint, 1960). Woody species present in the sample plots in addition to those mentioned above, but in minor quantities, are largetooth aspen (*Populus grandidentata* Michx.), white spruce (*Picea glauca* [Moench] Voss), black spruce (*Picea mariana* [Mill.] B.S.P.), balsam fir (*Abies balsamea* [L.] Mill.), eastern white pine (*Pinus strobus* L.), black ash (*Fraxinus nigra* Marsh.), American beech (*Fagus grandifolia* Ehrh.), beaked hazel (*Corylus cornuta* Marsh.), alternate-leaved dogwood (*Cornus alternifolia* L.f.), and serviceberry (*Amelanchier* spp.).

Methods

Field work

The data were collected during the period June-August of 1978, following the procedure outlined in a previously prepared manual (Alemdag, 1980). Eighteen 0.04-ha (20 m × 20 m) sample plots were established in the stands described in order to obtain stand data and to sample as wide a range of tree size as possible for the various species. For sampling purposes, all living trees equal to or larger than 5.1 cm diameter at breast height outside bark (dbhob) were tallied in each plot by species, dbhob, and total tree height (h). Two subplots, 5 m × 5 m and 2 m × 2 m, were then randomly established at one corner of the plot. In the first subplot, all living trees from 0.1 cm to 5.0 cm dbhob, inclusive, were tallied. In the second subplot, all living woody plants up to 1.30 m tall were counted in two height classes (0.31 m–0.80 m and 0.81–1.30 m).

Trees were selected for weighing, using a stratified sampling procedure. For each species, two or more sample trees per 5-cm dbhob class were taken across the range of diameters and heights distributed over the 18 plots. Trees were cut to about a 0.30-m stump and the necessary diameter and length measurements were taken on the stem and the stump, including that of diameter at ground level. Each sample tree was separated into its component twigs and leaves, large and small live branches, dead branches, lower third, middle third, and upper third of the merchantable bole (total bole, if not merchantable), and top. Green mass (GM), to the nearest 0.1 kg, of each of these components was taken in the woods immediately after the components were separated, using a direct-reading tensiometer scale. Four sample disks were removed from the stems of the trees of merchantable size: at breast height (1.30 m) and at 1/3, 2/3, and the top of merchantable height. From the unmerchantable trees, two disks were removed: at breast height and at 1/2 the tree length. Also, samples were taken from twigs and leaves and

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*The term *mass* rather than the term *weight* is used throughout this report as recommended in the *Canadian Metric Practice Guide* (Canadian Standards Association; Rexdale, Ontario; 1979).

Table 1. Basic data for trees 5.1 cm dbhob and larger

		Diameter at Breast Height Outside Bark (cm)			Height (m)			Green Mass (kg)		
	n	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Trembling aspen	40	17.1	10.0	5.2 – 41.8	16.3	6.3	6.7 – 26.8	343.5	449.8	9.8 – 1490.5
White birch	45	19.4	5.2	7.6 – 29.7	18.5	3.4	8.8 – 22.3	329.0	180.4	25.7 – 773.2
Sugar maple	17	13.4	6.1	5.1 – 27.1	12.9	3.6	7.3 – 18.0	150.9	161.3	9.5 – 629.8
Red maple	24	14.3	5.1	5.8 – 25.8	12.9	2.7	8.0 – 20.2	122.8	108.5	17.1 – 465.1
Red oak	42	24.5	7.1	5.5 – 40.4	18.0	3.6	8.1 – 23.0	569.8	386.1	16.1 – 1512.3
Ironwood	14	7.7	3.5	5.2 – 18.5	8.6	1.7	6.3 – 11.9	30.1	34.3	9.7 – 131.9

from branches. All samples were sent to the laboratory in sealed polyethylene bags. A total of 197 sample trees of 0.1 cm dbhob and larger were taken.

The means, standard deviations, and ranges of some variables of sample trees equal to and larger than 5.1 cm are given in Table 1. It shows that, for all species together, diameter at breast height outside bark ranged from 5.1 cm to 41.8 cm, total height from 6.3 m to 26.8 m, and green mass of the whole tree from 9.5 kg to 1512.3 kg.

Laboratory work

In the laboratory, immediately after the bags were opened, the samples other than stem disks were weighed green on a precision balance. A wedge of wood was cut from each of the stem disks for the determination of wood density. The green volume of each wedge was obtained by displacement of water.* Bark on the remaining part of the stem disks was separated from the wood and they were weighed separately.

All the samples, including wedges, were then ovendried at 105°C ± 3° in a fan-vented oven and the ovendry mass (OM) of each was recorded. All measurements of mass were made to the nearest 0.1 g.

Basic computations

Each sample tree was worked up separately to obtain basic data for analysis. The values included inside and outside volume of stem in cubic metres and green and ovendry masses of stem wood, stem bark, branches, and twigs and leaves in kilograms. Ovendry masses of the tree components were calculated by multiplying the ratios of OM to GM of the samples by the total GM of the components. Average wood density of the stem wood of each individual tree was also calculated in terms of (ovendry mass, g)/(green volume, cm^3). All these data, together with dimensional measurements, were recorded on computer tapes.

*This was done under the existing conditions of the water temperature and the atmospheric pressure in the laboratory and not converted into standard temperature and pressure conditions.

Analyses

A series of analyses was conducted for the estimation of aboveground ovendry masses of tree components and ratios of ovendry mass of single trees using the data of each species separately, because statistical tests to combine some or all species indicated that they were significantly different. In addition, the average wood densities of the tree species and the ovendry mass of stands were calculated.

The equations developed are for stem wood, stem bark, live branches, twigs and leaves, and whole tree. Stem wood and stem bark include stump and top portions of the tree, live branches include wood and bark, and whole tree is all the aboveground components other than dead branches. Independent variables used in the analyses are the readily obtainable diameter at breast height outside bark and total height of single trees. The explanations of these equations follow.

Ovendry masses of components and of whole tree

In a number of biomass studies, the mass/dimensional relationships of single trees are expressed in the logarithmic forms of the following two models:

$$OM = a \cdot (dbhob)^b \qquad (1)$$

$$OM = a \cdot (dbhob)^b \cdot h^c \qquad (2)$$

where OM is ovendry mass of components or of whole tree, dbhob and h are as previously defined, a is coefficient, and b and c are exponents (Stanek and State, 1978). However, logarithmic forms of tree-mass equations would present major problems in forecasting stand growth, mainly because, for a given species, the exponents would vary from one component of total mass to another, and therefore, should the component masses be additive for the whole-tree mass, it would be purely coincidental. Furthermore, Equation 1 represents a local mass equation applicable only to the stands from which the samples have been drawn. Regional inventories need two-way, or standard, equations giving mass by dbhob and h. Such equations are also essential for stand growth forecasting, because growth in height is an important component of total growth, and its effect on stand growth can be determined only by the use of standard equations. Thus, a simple linear regression equation containing dbhob and h was preferred over logarithmic expressions both for the components and for the whole tree, and the following models were tested. Each of these, if used for all the components without dropping any of its terms, has the property of adding up to the mass of the whole tree. Thus

$$OM = b_0 + b_1 \cdot (dbhob)^2 + b_2 \cdot h + b_3 \cdot (dbhob)^2 \cdot h \quad (3)$$
$$OM = b_1 \cdot (dbhob)^2 + b_2 \cdot h + b_3 \cdot (dbhob)^2 \cdot h \quad (4)$$
$$OM = b_0 + b_1 \cdot (dbhob)^2 \cdot h \quad (5)$$
$$OM = b_1 \cdot (dbhob)^2 \cdot h \quad (6)$$

where OM is expressed in kilograms, dbhob in centimetres, and h in metres. Using Equations 3 and 4, it was found that the combined variable $(dbhob)^2 \cdot h$ accounted for most of the variation in ovendry mass of stem wood and of whole tree in all six species. Assuming that ovendry mass will be close to zero when dbhob is zero, Equation 6 was adopted for predicting ovendry masses of tree components and of the whole tree for trees with dbhob of 5.1 cm and larger. Trees having a dbhob from 0.1 cm to 5.0 cm were analyzed separately but only for the ovendry mass of the whole tree. Woody plants of heights up to 1.30 m were evaluated for their total mass, using all species together and taking the averages of several plants for the two height classes.

Ratios of ovendry masses of components and of whole tree

Ratios of ovendry masses of tree components to ovendry mass of whole tree were regressed against $dbhob^2$, dbhob, and h variables for trees equal to or larger than 5.1 cm dbhob. A similar relationship was tried for the ratios of component ovendry and whole tree ovendry masses to stem wood ovendry mass, employing the same regression model. At the same time, these were calculated by: (1) taking the ratios of b_1 coefficients of Equation 6, and (2) using the original ovendry mass data of the sample trees with the following formula:

$$\text{Ratio} = \Sigma Y / \Sigma X \quad (7)$$

where Y is ovendry mass of components and X is ovendry mass of whole tree or of stem wood.

Ratios between ovendry and green masses of components and of whole tree

It is sometimes useful to have an idea about the moisture content of a tree through the ratios between the ovendry and the green masses of its components together with the location from which and the time at which the data were collected. Also, by the use of these ratios, a green mass can easily be converted into ovendry mass. On the basis of the analyses indicating that these ratios, or conversion factors, are constant for each component, their average values were calculated for trees of 5.1 cm dbhob and larger using Equation 7 as suggested by Snedecor and Cochran (1971), where Y represents ovendry mass and X green mass of components and of whole tree.

Wood densities

Wood densities at four locations on trees of merchantable size and at two locations on those of unmerchantable size were weighted by disk diameters to obtain the average value of each individual tree for its total bole. These values for trees 5.1 cm dbhob and larger were regressed using a model similar to Equation 3, after replacing $dbhob^2$ with dbhob. At the same time, average wood densities were calculated for each species.

Ovendry mass of stands

In order to calculate the average total ovendry mass, on an area basis, of stands sampled, the sample plots were first classified by subtype, according to percentage occurrence by species of stand basal area. Two subtypes were so identified: (1) red oak–white birch, containing 11 sample plots, and (2) trembling aspen–maple–white birch, containing 5 sample plots. Stand tables for each of these subtypes were then prepared by taking the averages of sample plots, including woody plants shorter than 1.31 m. The aboveground ovendry mass of each 2.0-cm dbhob class was computed and summed for total stand mass, using each species' OM/dbhob values. Ovendry masses of black spruce, white spruce, and balsam fir were taken from a similar study of softwoods in the same area. For largetooth aspen and the other species, the ovendry mass of closest species were used. Furthermore, mass distribution for any given upper part of the dbhob classes was calculated for each subtype in order to illustrate the significance of the components of stand structure. In addition to these, the standing crop density (SCD) as an indicator of the compactness of the dry organic matter of a given stand was calculated as ovendry mass per unit volume of stand space (kg/m^3), using

$$SCD = (OM \text{ in kg})/(\text{area in } m^2 \times \text{average stand height in m})$$

as suggested by Kira and Shidei (1967).

Results and discussion

The adopted equations for components presented in this paper for trees with dbhob larger than 5.0 cm is based on readily measurable tree variables, diameter at breast height outside bark, and height, which are also available for most forest inventories. These equations are simple linear regression and can conveniently be used in the calculation of aboveground ovendry mass of forest-grown single trees (Table 2). Stand mass has to be calculated by these single-tree equations with the stand data. Local mass equations can be derived from these standard equations after establishing h/dbhob curves of a species in a given area. Since the calculation of the total mass of an individual tree by summing the masses of the components produces the same result as does employing the whole-tree mass equation alone (See Table 2 for the means and the coefficients), either approach can be followed; it depends upon purpose and convenience.

As mentioned earlier, the combined variable $(dbhob)^2 \cdot h$ accounted for almost all of the variation in the ovendry mass of stem wood and of the whole tree, perhaps because of the close and direct correlation between tree volume and mass. The same combined variable was highly significant for most of the component masses of all six species too; however, as indicated by the coefficient of determination (r^2) and the standard error of estimate (SEE%), the reliability of Equation

Table 2. Prediction equations for ovendry mass for trees 5.1 cm dbhob and larger

Prediction:	b_1	r^2	SEE%	Mean (kg)	Range (kg)
	Trembling Aspen n = 40				
Stem wood	$1.4755 \cdot 10^{-2}$	0.988	14.6	128.6	3.2 – 549.2
Stem bark	$3.8799 \cdot 10^{-3}$	0.971	23.2	33.3	1.1 – 160.3
Live branches	$3.3181 \cdot 10^{-3}$	0.907	47.6	26.5	0.3 – 174.8
Twigs and leaves	$5.0703 \cdot 10^{-4}$	0.339	65.5	6.5	0.4 – 18.5
Whole tree	$2.2460 \cdot 10^{-2}$	0.988	14.3	194.9	5.8 – 856.7
	White Birch n = 45				
Stem wood	$1.6551 \cdot 10^{-2}$	0.965	9.8	133.0	9.1 – 293.6
Stem bark	$3.0491 \cdot 10^{-3}$	0.926	13.2	25.0	1.3 – 48.6
Live branches	$3.5654 \cdot 10^{-3}$	0.647	50.5	26.6	0.8 – 92.2
Twigs and leaves	$9.9420 \cdot 10^{-4}$	0.732	32.7	7.9	1.2 – 25.6
Whole tree	$2.4160 \cdot 10^{-2}$	0.967	9.9	192.5	13.6 – 448.7
	Sugar Maple n = 17				
Stem wood	$1.9116 \cdot 10^{-2}$	0.977	15.4	63.7	3.8 – 240.5
Stem bark	$2.9076 \cdot 10^{-3}$	0.884	28.0	10.8	0.9 – 31.8
Live branches	$6.5825 \cdot 10^{-3}$	0.789	77.4	17.4	0.2 – 124.7
Twigs and leaves	$1.4771 \cdot 10^{-3}$	0.898	35.7	4.8	0.2 – 22.7
Whole tree	$3.0083 \cdot 10^{-2}$	0.985	13.5	96.7	6.2 – 419.7
	Red Maple n = 24				
Stem wood	$1.3709 \cdot 10^{-2}$	0.918	26.2	47.5	6.4 – 201.3
Stem bark	$2.5096 \cdot 10^{-3}$	0.929	24.6	8.7	0.8 – 32.5
Live branches	$3.3024 \cdot 10^{-3}$	0.308	102.9	12.5	1.9 – 75.8
Twigs and leaves	$1.1318 \cdot 10^{-3}$	0.630	46.6	4.4	0.9 – 15.7
Whole tree	$2.0653 \cdot 10^{-2}$	0.909	26.4	73.1	10.2 – 274.4
	Red Oak n = 42				
Stem wood	$1.6965 \cdot 10^{-2}$	0.962	13.1	217.2	5.4 – 647.5
Stem bark	$3.1812 \cdot 10^{-3}$	0.835	21.7	43.7	1.0 – 103.0
Live branches	$4.9538 \cdot 10^{-3}$	0.525	80.0	58.1	0.4 – 309.2
Twigs and leaves	$6.3716 \cdot 10^{-4}$	0.236	52.4	9.3	0.4 – 22.4
Whole tree	$2.5737 \cdot 10^{-2}$	0.955	14.4	328.3	9.1 – 874.4
	Ironwood n = 14				
Stem wood	$1.5409 \cdot 10^{-2}$	0.947	23.8	12.1	3.0 – 48.1
Stem bark	$1.4320 \cdot 10^{-3}$	0.593	45.2	1.4	0.6 – 3.9
Live branches	$4.1465 \cdot 10^{-3}$	0.953	29.8	2.8	0.3 – 13.7
Twigs and leaves	$2.4322 \cdot 10^{-3}$	0.906	35.6	1.8	0.7 – 8.9
Whole tree	$2.3420 \cdot 10^{-2}$	0.963	20.4	18.1	6.3 – 74.5

Note: The equations are in the form of $OM = b_1 \cdot (dbhob)^2 \cdot h$.

6 is better for stem or whole-tree mass than for the other component masses. Using some additional independent variables, such as stand or single-tree density, site, and age, in the regression together with tree size may possibly provide better estimates for stem bark, live branches, and twigs and leaves.

An equation for the ovendry mass of whole tree for trees of all species having a dbhob from 0.1 cm to 5.0 cm was developed as given below:

$$OM = 0.030 + 0.024254 \cdot (dbhob)^2 \cdot h \qquad (8)$$

where OM, dbhob, and h are as defined earlier. Ovendry mass of woody plants (whole tree) shorter than 1.31 m are as follows:

Height class 1 = 0.008 kg/stem
Height class 2 = 0.022 kg/stem

Regressions for the prediction of ratios of ovendry masses of components to whole tree or stem wood, using the tree variables of dbhob and h, produced unsatisfactory results. However, the average values of these ratios for all sizes of trees, established in either way as explained earlier, can be suggested for practical purposes (Table 3). These ratios can conveniently be employed for estimating the component masses where ovendry mass of stem wood is calculated using wood density and inside-bark stem volume of individual trees. It will be seen from Table 3 that, on the average, stem wood contains around 66%, live branches 17%, stem bark 12%, and twigs and leaves 5% of the whole-tree ovendry mass. As an average value, 9% of stem wood or 8% of stem wood and bark is stump wood with bark.

Converting the green masses of components to their ovendry masses presented no problem. These ratios, or conversion factors, varied for stem wood, for instance, from 0.552 to 0.661 among the six species (Table 4). They are, at the same time, the indicators of ovendry matter and water content of the tree components. For example, for sugar maple, 66.1% of the green mass of stem wood is dry matter and 33.9% is water; or, the ratio of dry matter to water is 1.95.

The stem's wood density was found to have a weak correlation with dbhob and h, and because of this, the average wood density of each species was thought to be satisfactory for use. These densities of stem wood (Table 5) differed slightly from those of the same species reported by Jessome (1977). Although the average values given in the present report are higher by 0.029, 0.032, 0.036, and 0.045 for white birch, trembling aspen, sugar maple, and red maple, respectively, and lower by 0.015 for red oak, these differences may be due to local conditions or to different sample sizes and can be considered insignificant.

Average stand composition, by species, of the two subtypes where 16 of the sample plots were located can be seen in Tables 6*a* and 6*b*. The per-hectare ovendry mass of these subtypes is provided in Tables 7*a* and 7*b*. As will be seen, for trees equal to and larger than 0.1 cm dbhob, the stand mass was found to be 178 700 kg/ha (nearly 179 metric tons/ha) and 140 520 kg/ha (about 141 metric tons/ha) for red oak–white birch and trembling aspen–maple–white birch subtypes, respectively. With the inclusion of the woody plants from 0.31 m to 1.30 m high, these totals were 179 117 kg/ha and 140 800 kg/ha, respectively. These values may be

Table 3. Percentages of ovendry mass for trees 5.1 cm dbhob and larger

	Stem Wood		Stem Bark		Live Branches		Twigs and Leaves		Whole Tree	
	In Ovendry Mass of Whole Tree									
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)		
Trembling aspen	65.7	66.0	17.3	17.1	14.8	13.6	2.2	3.3	100.0	
White birch	68.5	69.1	12.6	13.0	14.8	13.8	4.1	4.1	100.0	
Sugar maple	63.5	65.9	9.7	11.1	21.9	18.0	4.9	5.0	100.0	
Red maple	66.4	65.0	12.1	11.9	16.0	17.1	5.5	6.0	100.0	
Red oak	65.9	66.2	12.4	13.3	19.2	17.7	2.5	2.8	100.0	
Ironwood	65.8	66.9	6.1	7.7	17.7	15.5	10.4	9.9	100.0	
	In Ovendry Mass of Stem Wood									
			(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Trembling aspen	100.0		26.3	25.9	22.5	20.6	3.4	5.1	152.2	151.6
White birch	100.0		18.4	18.8	21.5	20.0	6.0	5.9	145.9	144.7
Sugar maple	100.0		15.2	17.0	34.4	27.3	7.7	7.5	157.3	151.8
Red maple	100.0		18.3	18.3	24.1	26.3	8.3	9.3	150.7	153.9
Red oak	100.0		18.7	20.1	29.2	26.7	3.8	4.3	151.7	151.1
Ironwood	100.0		9.3	11.6	26.9	23.1	15.8	14.9	152.0	149.6

(1) Using regression coefficients. (2) Using the formula $\Sigma Y/\Sigma X$.

Table 4. Ratios of ovendry to green mass for trees 5.1 cm dbhob and larger

	Stem Wood	Stem Bark	Live Branches	Twigs and Leaves	Whole Tree	n
Trembling aspen	0.564	0.637	0.538	0.462	0.567	40
White birch	0.584	0.663	0.589	0.433	0.585	45
Sugar maple	0.661	0.677	0.630	0.435	0.640	17
Red maple	0.605	0.606	0.602	0.485	0.595	24
Red oak	0.552	0.690	0.619	0.484	0.576	42
Ironwood	0.632	0.569	0.603	0.465	0.601	14

Table 5. Average wood densities for trees 5.1 cm dbhob and larger

	Wood Density (g/cm^3)	Number of Trees	Number of Samples
Trembling aspen	0.406 *(0.374)**	40 *(20)*	114
White birch	0.535 *(0.506)*	45 *(16)*	160
Sugar maple	0.633 *(0.597)*	17 *(19)*	42
Red maple	0.561 *(0.516)*	24 *(6)*	52
Red oak	0.566 *(0.581)*	42 *(11)*	156
Ironwood	0.652 *(0.652)*	14 *(6)*	28

*Figures in parentheses were reported by Jessome (1977).

compared to 155 tons/ha (above- and belowground) in mature hardwood stands in Maine, reported by Young (1977), and to 167 tons/ha in aspen stands in Minnesota, reported by Alban *et al*. (1978).

Mass distributions by dbhob classes showed that 95% and 90% of the total stand mass is occupied by 9.1-cm and larger trees in red oak–white birch and in trembling aspen–maple–white birch subtypes, respectively, and half of the total stand mass by trees of 25.1 cm of dbhob and up. As illustrated in Tables 7*a* and 7*b*, the contribution of the small trees to the total stand mass is very minor. To increase percentages of number of trees, for instance, from 9.6 to 100 in the red oak–white birch subtype, will increase percentages of mass only from 95.1 to 100. An example of the relationship between the number of trees and the stand mass is as follows (see Table 7*a*): trees of 21.1 cm of dbhob and up occupy only about 3% of the total number of trees downward from the largest tree but provide about 66% of the total stand mass.

For red oak–white birch and trembling aspen–maple–white birch subtypes, the ovendry organic matter per cubic metre of stand space (the standing crop density) is found, respectively, to be 1.021 kg/m^3 and 0.803 kg/m^3 for trees of 0.1 cm and larger and 0.904 kg/m^3 and 0.662 kg/m^3 for trees equal to and larger than 9.1 cm dbhob. W.D. Johnstone and E.B. Peterson reported standing crop densities from 0.54 to 1.63 kg/m^3 for *Populus* stands of Alberta.*

Although the findings presented in this paper could be used for these tree species growing under ecological conditions similar to those of the Petawawa National Forestry Institute's research forest, more generally applicable results could be obtained by pooling as much data as possible from throughout a larger region and developing the same type of relationships as described above. This procedure is now being followed for trembling aspen and white birch of Ontario.

Finally, the high coefficient of determination and relatively low standard error of estimate values indicate that the adopted model (Equation 6) for the estimation of ovendry masses of components and of the whole tree fits the data very well. This was verified by the close similarities of the ratios of ovendry masses of components and of whole tree or stem wood calculated by using, first, the regression coefficients and second, the formula $\Sigma Y/\Sigma X$.

*Personal communications, December 1979.

Table 6*a*. Average stand composition of red oak–white birch subtype, trees 9.1 cm dbhob and larger

	Basal Area (%)	Number of Trees (%)
Red oak	45.1	31.2
White birch	33.8	35.4
Sugar maple	8.0	18.0
Largetooth aspen	6.4	4.7
Balsam fir	1.5	2.5
Red maple	1.2	2.5
Ironwood	0.4	1.3
White spruce	0.2	0.3
Others	3.4	4.1

Quadratic mean diameter:
For trees of 0.1 cm and larger = 6.6 cm
For trees of 9.1 cm and larger = 20.0 cm
Average stand height weighted by basal area:
For trees of 0.1 cm and larger = 17.5 m
For trees of 9.1 cm and larger = 18.8 m

Note: The average stand composition is based on 11 sample plots.

Table 6*b*. Average stand composition of trembling aspen–maple–white birch subtype, trees 9.1 cm dbhob and larger

	Basal Area (%)	Number of Trees (%)
Trembling aspen	54.7	50.6
White birch	13.9	11.2
Red maple	9.7	11.2
Sugar maple	8.5	11.8
White spruce	5.5	5.3
Ironwood	4.8	5.3
Balsam fir	0.5	2.0
Others	2.4	2.6

Quadratic mean diameter:
For trees of 0.1 cm and larger = 5.6 cm
For trees of 9.1 cm and larger = 18.8 cm
Average stand height weighted by basal area:
For trees of 0.1 cm and larger = 17.5 m
For trees of 9.1 cm and larger = 19.1 m

Note: The average stand composition is based on 5 sample plots.

Table 7*a*. Distribution by dbhob class of number of trees and ovendry mass of whole tree for red oak–white birch subtype

dbhob Class (cm)	Average Number of Trees/ha		Average Whole-Tree Ovendry Mass/ha	
	Number*	Cumulative (%)	(kg)*	Cumulative (%)
0.1 – 1.0	5 000	100.0	500	100.0
1.1 – 3.0	1 850	43.4	900	99.7
3.1 – 5.0	660	22.4	1 600	99.2
5.1 – 7.0	290	14.9	2 400	98.3
7.1 – 9.0	177	11.6	3 350	97.0
9.1 – 11.0	140	9.6	4 600	95.1
11.1 – 13.0	116	8.0	6 500	92.5
13.1 – 15.0	100	6.7	8 200	88.9
15.1 – 17.0	87	5.6	9 850	84.3
17.1 – 19.0	75	4.6	11 100	78.8
19.1 – 21.0	65	3.75	12 200	72.6
21.1 – 23.0	55	3.01	13 100	65.8
23.1 – 25.0	47	2.39	13 800	58.5
25.1 – 27.0	40	1.86	14 100	50.8
27.1 – 29.0	32	1.41	13 500	42.9
29.1 – 31.0	25	1.05	12 300	35.3
31.1 – 33.0	20	0.77	11 100	28.4
33.1 – 35.0	15	0.54	9 700	22.2
35.1 – 37.0	11.4	0.37	8 400	16.8
37.1 – 39.0	8.4	0.24	7 000	12.1
39.1 – 41.0	6.3	0.15	5 900	8.2
41.1 – 43.0	4.6	0.08	5 100	4.9
43.1 – 45.0	–		–	
45.1 – 47.0	–		–	
47.1 – 49.0	–		–	
49.1 – 51.0	–		–	
51.1 – 53.0	2.3	0.03	3 500	2.0
Total	8 827		178 700	

Woody plants 1.30 m and smaller in height:
Class 1 = 20 909 trees/ha = 167 kg/ha
Class 2 = 11 364 trees/ha = 250 kg/ha

*Curved values (free-hand).

Table 7*b*. Distribution by dbhob class of number of trees and ovendry mass of whole tree for trembling aspen–maple–white birch subtype

dbhob Class (cm)	Average Number of Trees/ha		Average Whole-Tree Ovendry Mass/ha	
	Number*	Cumulative (%)	(kg)*	Cumulative (%)
0.1 – 1.0	5 700	100.0	570	100.0
1.1 – 3.0	2 400	45.5	1 900	99.6
3.1 – 5.0	850	22.5	3 000	98.2
5.1 – 7.0	450	14.4	3 900	96.1
7.1 – 9.0	300	10.1	4 650	93.3
9.1 – 11.0	200	7.2	5 350	90.0
11.1 – 13.0	125	5.3	5 900	86.2
13.1 – 15.0	85	4.1	6 400	82.0
15.1 – 17.0	64	3.28	6 900	77.4
17.1 – 19.0	51	2.67	7 300	72.5
19.1 – 21.0	42	2.18	7 700	67.3
21.1 – 23.0	35	1.78	8 050	61.8
23.1 – 25.0	29	1.44	8 350	56.1
25.1 – 27.0	25	1.16	8 550	50.2
27.1 – 29.0	21	0.92	8 600	44.1
29.1 – 31.0	18	0.72	8 500	38.0
31.1 – 33.0	15	0.55	8 300	32.0
33.1 – 35.0	12.6	0.41	8 100	26.1
35.1 – 37.0	10.9	0.29	7 800	20.3
37.1 – 39.0	9.1	0.19	7 500	14.7
39.1 – 41.0	–		–	
41.1 – 43.0	6.8	0.10	7 200	9.4
43.1 – 45.0	–		–	
45.1 – 47.0	–		–	
47.1 – 49.0	4.6	0.04	6 000	4.3
Total	10 454		140 520	

Woody plants 1.30 m and smaller in height:
Class 1 = 13 000 trees/ha = 104 kg/ha
Class 2 = 8 000 trees/ha = 176 kg/ha

*Curved values (free-hand).

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