BIOMASS EQUATIONS FOR SEVEN MAJOR MARITIMES TREE SPECIES

by

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ABSTRACT

Equations are given for estimating fresh and ovendry weights of biomass components for seven major Maritimes tree species (balsam fir, white spruce, red/black spruce, jack pine, red maple, white birch, and trembling aspen). Two equations are given for each component, one using diameter at breast height (DBH) alone as the independent variable, and the other using both DBH and height. A set of stump biomass equations are included which use DBH and stump height as independent variables. These equations are based on 1400 sample trees from throughout New Brunswick and Nova Scotia. Stem disc and branch samples were oven-dried and used to estimate ovendry/fresh weight ratios for each sample tree. A FORTRAN subroutine is included to assist in tree biomass calculations.

RESUME

Ce rapport présente des équations permettant d'estimer les masses à l'état vert et à l'état sec des composantes de la biomasse pour sept essences importantes des Maritimes: le sapin baumier, l'épinette blanche, l'épinette rouge-noir, le pin gris, l'érable rouge, le bouleau à papier et le peuplier faux-tremble. Il donne deux équations pour chaque composante, l'une utilisant le diamètre à hauteur de poitrine (dhp) comme unique variable indépendante et l'autre utilisant le dhp et la hauteur. Une série d'équations pour la biomasse de la souche utilisant le dhp et la hauteur de la souche comme variables indépendantes sont également incluses. Ces équations reposent sur un échantillon de 1400 arbres choisis dans l'ensemble du Nouveau-Brunswick et de la Nouvelle-Ecosse. Le rapport de la masse anhydre à la masse à l'état frais a été estimé pour chaque arbre à l'aide d'échantillons de la tige et des branches qui ont été séchés à l'étuve. Un sous-programme FORTRAN destiné à faciliter les calculs de la biomasse des arbres est présenté.

FOREWORD

ENFOR is the acronym for the Canadian Government's ENergy from the FORest (ENergie de la FORêt) program of research and development aimed at securing the knowledge and technical competence to facilitate in the medium to long-term a greatly increased contribution from forest biomass to our nation's primary energy production. This program is part of a much larger federal government initiative to promote the development and use of renewable energy as a means of reducing dependence on petroleum and other non-renewable energy sources.

The Canadian Forestry Service (CFS) administers the ENFOR Biomass Production program component which deals with such forest-oriented subjects as inventory, harvesting technology, silviculture and environmental impacts. (The other component, Biomass Conversion, deals with the technology of converting biomass to energy or fuels and is administered by the Renewable Energy Branch of the Department of Energy, Mines and Resources.) Most Biomass Production projects, although developed by CFS scientists in the light of ENFOR program objectives, are carried out under contract by forestry consultants and research specialists. Contractors are selected in accordance with science procurement tendering procedures of the Department of Supply and Services. For further information on the ENFOR Biomass Production program, contact ....

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... or a CFS research laboratory.

This report, based on ENFOR project P-159, was prepared by the Canadian Forestry Service. Field data were collected under contract (DSS Contract Nos. OSC80-00003) by Woodlot Service (1978) Ltd.

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INTRODUCTION

The sharp increase in oil prices over the last decade has prompted widespread efforts to develop alternate energy sources and technologies and has also made investments in conservation of energy much more attractive. One of these efforts, the federal government's ENFOR program, is a seven year forest biomass research and development program which began in 1977 with two main objectives: 1) quantification of the forest biomass resources available, and 2) development of economically feasible systems for harvesting biomass and converting it to useful forms of energy or fuels. One of the major results of the biomass measurement work being carried out under this program is a national biomass inventory being compiled by the Forestry Statistics and Systems Branch of the Canadian Forestry Service in cooperation with the provincial forestry agencies and due to be published in 1984. These biomass inventory statistics will be derived using two basic methods: 1) application of biomass/volume ratios to existing provincial volume inventory figures and 2) application of tree biomass equations to existing stand table and inventory plot data. The second approach, which is more accurate but more time-consuming, is being used to produce the biomass inventories for the Maritime Provinces.

Biomass equations for several Maritimes species have been developed by Baskerville (1965), MacLean and Wein (1976), Ker (1980 a, b), Ker and van Raalte (1981), Duinker (1981) and Telfer (1969). Most of these equations are based on relatively small samples from a specific area within the Maritimes. Baskerville's (1965) equations, for example, are based on data from the Green River watershed in northwestern New Brunswick.

This report provides biomass equations for seven major Maritimes tree species, based on 1400 sample trees which were distributed throughout New Brunswick and Nova Scotia. These equations and others will be used in deriving the biomass inventory statistics for the three Maritime provinces, and can be used in a wide variety of other applications. Biomass equations and studies for other species and regions have been summarized by Stanek and State (1978), Tritton and Hornbeck (1982), Hitchcock and McDonnell (1979) and Young (1976).

DATA COLLECTION

Sample tree selection

Sample trees were selected from random locations throughout New Brunswick and Nova Scotia during the summers of 1980, 1981, and 1982 (Fig. 1). Two hundred pairs of random (X,Y) coordinates were generated by computer and plotted on base maps. One sample tree of each of the seven species was selected from within a 5-mile radius of the plot center. The seven species sampled were the most important commercial species of the Maritimes:

1) balsam fir (*Abies balsamea* (L.) Mill.)
2) white spruce (*Picea glauca* (Moench) Voss)
3) black/red spruce (*Picea mariana* (Mill.) B.S.P. and *Picea rubens* Sarg.)
4) jack pine (*Pinus banksiana* Lamb.)
5) red maple (*Acer rubrum* L.)
6) white birch (*Betula papyrifera* Marsh.)
7) trembling aspen (*Populus tremuloides* Michx.)

Any species not found within the 5-mile radius was sampled at the next plot along with the samples for that plot. Sampling was carried out by the contractor (Woodlot Service (1978) Ltd.), in consultation with provincial and industry foresters, who provided assistance in locating particular species.

Sample trees were selected from throughout the full range of tree diameters to minimize the variance of the regression coefficients which were estimated from the data and thereby help to reduce the total sampling error of the biomass inventories. A total of 1400 sample trees was measured over the 3-year sampling period - 200 for each of the seven species. The distribution of sample trees by diameter class, species, and province is given in Table 1.

Field measurements and procedures

Diameter outside bark was measured at 1.3 m above ground. Crown width was recorded as the average of two measurements taken at right angles to each other. Crown class, cover type, slope percent, and aspect were recorded. The tree was then felled and total height, stump height, and live crown length were measured.

Stem discs were cut at 2-m intervals, starting at the base of the stem. The fresh weight of each 2-m stem section and top was obtained using platform scales (±0.1 kg). Discs were labelled and the fresh weight (±0.1 g) of wood and of bark was obtained for each disc at a trailer located near the work site.

A stratified sampling system (Cochran 1967) was used for estimating crown weights. Live softwood branches of each sample tree were sorted into 2-cm size classes (strata) using the diameter of the branch at 3 cm from the base as the stratification criterion. The total fresh weight of each stratum was obtained and one branch was randomly selected from each stratum for dry weight determination.

Live hardwood branches were cut into sections not longer than 2 m in length and then sorted into 2-cm size classes based on the mid-diameter of the section. The smallest, foliage bearing branches were all assigned to the 0 to 2-cm class. As with softwoods, the total fresh weight of each stratum was obtained using platform scales. Two sample branches were randomly selected from the 0 to 2-cm class and their combined fresh weight was determined. For each of the remaining strata, five branch discs were cut from the branches in that stratum, and their total fresh weight was measured at the trailer.

Dead branches were weighed separately. For softwoods, one dead sample branch was selected and its fresh weight was obtained. For hardwoods, the sample consisted of three branch discs, whose total fresh weight was determined.

All sample discs and branches were bagged, labelled, and sent to the Canadian Forestry Service laboratory in Fredericton for oven-drying and dry weight measurements. Ovendry weights of sample material provided the basis for conversion of fresh weights to ovendry weights.

Laboratory measurements and procedures

All sample discs and branches were oven-dried for at least 24 h and then weighed. Softwood foliage was separated from branches after drying using a standard winnowing machine fitted with appropriate screens. Jack pine and hardwood foliage was separated manually. Dry foliage and branches (wood plus bark) were weighed separately for each branch sample. The total dry weight of each set of hardwood branch discs was determined. Branch wood and bark were not separated. Stem disc wood and bark samples were dried and weighed separately.

Climatic data

The average values of five climatic variables were obtained for each sample plot from available climatic maps (Can. Dep. Energy, Mines, Resources 1974, Gates 1975) and used to test for large-scale differences in tree biomass relationships which might be related to climatic differences within the region. The five variables selected for testing were 1) growing degree-days, 2) mean total precipitation (May to September), 3) mean annual temperature, 4) July mean temperature, and 5) mean total annual precipitation.

ANALYSIS OF DATA

Data analysis involved two main steps: 1) calculation of fresh and ovendry weight of each biomass component for each sample tree, and 2) derivation of a set of regression equations for predicting biomass component weights from tree diameter and height. These two phases of analysis are described separately in the following sections.

Estimation of component weights of sample trees

1) Stem components

Stump weights were estimated using the observed stump height, tree diameter (DBH), basic relative densities (Can. Dep. Res. Dev 1951, Mullins and McKnight 1981), fresh and ovendry weights of the first stem disc, and a taper model (Alemdag and Honer 1973; Honer et al. 1983) which gives stump diameter as a function of stump height and tree diameter. Ovendry weight of stump wood was first calculated from the basic relative density, DBH, stump height, and a volume integral:

$$OSTMPW=0.07854BRD\int_0^S(b_3+D(1-0.04365b_2)(b_4+b_5\ln(1.6764/(S+0.3048))))^2dS$$

where

OSTMPW = ovendry weight of stump wood

BRD = basic relative density (specific gravity)

S = stump height (m)

D = diameter at 1.3 m outside bark

b_2, b_3, b_4, b_5 = regression coefficients (from Honer et al. 1983)

ln = natural logarithm

The remaining stump weights were then estimated by multiplying the appropriate weight ratio obtained from the first stem disc to the ovendry or fresh weight of stump wood:

$$FSTMPW = (w_1/w_1')\ OSTMPW$$

$$OSTMPB = (b_1'/w_1)\ FSTMPW$$

$$FSTMPB = (b_1/w_1)\ FSTMPW$$

where

FSTMPW = fresh weight of stump wood

OSTMPB = ovendry weight of stump bark

FSTMPB = fresh weight of stump bark

w_1 = fresh weight of wood, disc no. 1

w_1' = ovendry weight of wood, disc no. 1

b_1' = ovendry weight of bark, disc no. 1

b_1 = fresh weight of bark, disc no. 1

Above-stump stem weights were computed from the fresh and ovendry disc weights and the fresh stem section weights. Ovendry weight of stem wood, for example, was computed as

$$TDW = \sum_{i=1}^{n-1} ((w_i' + w_{i+1}')/(t_i + t_{i+1}))\ T_i + (w_n'/t_n)T_n + 10^{-3} \sum_{i=1}^{n} w_i'$$

where

TDW = ovendry weight of above-stump stem wood (kg)

w_i' = ovendry weight of wood for i^{th} disc (g)

T_i = total fresh weight of i^{th} stem section (kg)

t_i = total fresh weight of i^{th} disc (g)

n = number of discs for a given tree

Weights of fresh stem wood, fresh stem bark, and ovendry stem bark were calculated in a similar fashion. Stump weights were then added to above-stump stem weights to obtain total stem weights.

2) Crown components

Ovendry weights of foliage and branches were estimated using a stratified ratio-of-means estimator:

$$ODF = \sum_{i=1}^{k} AVGRF_i \cdot STRFW_i$$

$$ODCRWB = \sum_{i=1}^{k} AVGRWB_i \cdot STRFW_i$$

where

$$AVGRF_i = (\sum_{j=1}^{m} F_{ij})/(\sum_{j=1}^{m} FWSB_{ij})$$

$$AVGRWB_i = (\sum_{j=1}^{m} WB_{ij})/(\sum_{j=1}^{m} FWSB_{ij})$$

F_{ij} = ovendry weight of foliage for j^{th} sample in crown stratum i

$FWSB_{ij}$ = fresh weight of branch sample j in crown stratum i

WB_{ij} = ovendry weight of wood plus bark for branch sample j, crown stratum i

ODF = ovendry foliage weight for given sample tree

ODCRWB = ovendry weight of branches (wood plus bark) for a given sample tree

$STRFW_i$ = total fresh weight of i^{th} crown stratum for given sample tree

k = number of live crown strata for given tree

m = total number of branch samples in given crown stratum, all sample trees combined

Ovendry weight of dead branches was estimated in a similar way, using the ratio of mean ovendry weight to mean fresh weight of dead branch samples.

Derivation of tree biomass equations

The second phase of analysis consisted of development of a set of regression equations which could then be used for estimating the fresh and ovendry weights of the various tree components from measurements of tree diameter and height.

Three basic models were tested:

1) $W = aD^b$

2) $W = aD^bH^c$

3) $W = aD^bS^c$

where

W = weight (kg)

D = tree diameter at breast height outside bark (DBHOB) (cm)

H = total height (m)

S = stump height (m)

a,b,c = regression coefficients

Model 1 is intended for applications such as the New Brunswick biomass inventory where tree height data are not available. Model 2 requires an estimate of height but is more accurate than Model 1 and is thus recommended for general applications. Model 2 explicitly takes account of the variation in tree height for a given diameter which arises from differences in stand age, site quality, and stand density.

Model 3 was developed for estimation of stump weights from DBH and stump height.

The coefficients of these models were estimated using a nonlinear least squares procedure (SAS Inst 1979), as recommended by Payandeh (1981). Three types of plots were obtained for each model: 1) predicted versus observed weights, 2) residuals versus predicted weights, and 3) predicted and observed weights versus DBH. These plots were used to help identify gross measurement errors, data entry errors, and to identify any tree diameter values for which the model gave biased estimates of mean weight.

Since these models are nonlinear, they would give nonadditive estimates of biomass if separate equations were developed for each biomass component (Kozak 1970). Additivity can be simply achieved, however, by however, by developing equations for only a subset of all components and then calculating the weights of remaining components as the sum or difference of other components. For example, total stem weight can be calculated as the sum of predicted stem wood weight and predicted stem bark weight, rather than using a third equation. A general system of additive equations based on this approach was developed (Table 2).

Merchantable stem biomass for any top diameter and stump height can be estimated by applying the ratio(R) of merchantable volume to total volume (Honer et al. 1983) to total stem biomass, since volume is proportional to weight. This approach is incorporated in the general set of equations in Table 2. Coefficients for estimating this ratio are given in Honer et al. (1983) and in Table 3. Because this ratio requires an estimate of height, a set of height/diameter equations were developed for estimating height when Model 1 is used. The model used was Meyer's (1940) height/diameter equation:

$$H = 1.3 + b_o(1-\exp(b_1 D))$$

where

b_o, b_1 are regression coefficients.

The hypothesis of differences in weight/diameter relationships caused by climatic differences within the Maritimes was tested using the general linear model

$$\ln W = b_o + b_1 \ln D + b_2 \ln H + \sum_{i=1}^{5} c_i \ln X_i$$

where

W = total ovendry aboveground weight (kg)

$X_1, \ldots, X_5$ = climatic variables

The five climatic variables tested were described earlier in the DATA COLLECTION section. Regression coefficients (c_i) and R^2 values for all possible subsets of independent variables in this model were computed using Furnival and Wilson's (1974) algorithm for subset selection. The existence and magnitude of regional differences in tree biomass relationships was then evaluated by examining the statistical significance of the climate coefficients in the models and by the change in R^2 values caused by inclusion of climatic variables in the models.

RESULTS AND DISCUSSION

Mean weights and dimensions

The mean values of DBH, height, and weights of the various biomass components together with the standard deviations, ranges, and sample sizes are summarized in Table 4. The ranges of DBH and height in this table indicate the sizes of trees to which the biomass equations of this study are applicable.

Distribution of biomass within tree

The relative amounts of biomass in the various tree components will vary with the size of the tree and stand conditions such as age, density, and site quality. In general, larger trees will have a higher proportion of their total biomass in the form of stem wood, and conversely, smaller trees will have a greater proportion of their total biomass in the form of branches and foliage. We can, however, get a general idea of biomass distribution within the tree by expressing mean ovendry component weights as a percentage of mean total ovendry above-ground weight. These percentages are given in Table 5 and Figure 2. In Table 6, the mean ovendry component weights are expressed as a percentage of mean ovendry stem wood weights.

Ratio of ovendry to fresh weight

The ratios of 1) mean ovendry foliage weight to mean total fresh weight and 2) mean ovendry branch weight to mean total fresh weight for the branch sample data were used to convert fresh crown weights to ovendry foliage and branch weights, using the stratified ratio-of-means estimators described previously. These ratios are given in Tables 7 and 8, by species and crown stratum.

The AVGRWB ratios (Table 8) show little variation between the larger hardwood branch size classes, which suggests that two or three strata would be sufficient for estimating hardwood branch weights. This has been observed in previous studies (Ker 1980b). The AVGRWB ratios are similar to the ratios of ovendry branch weights to fresh branch weights reported by Alemdag (1981) for some of the same species.

The ratios of mean ovendry to mean fresh weights for the various components are given in Table 9. Average moisture content (dry basis) can be derived from these ratios using the formula

$$MC = 100(r^{-1} - 1)$$

where

MC = moisture content (%), dry basis.

r = ratio in Table 9

Tree biomass equations

Tests for regional differences in weight/diameter relationships revealed small but statistically significant differences for four of the seven species (jack pine, red maple, white birch, and trembling aspen). These differences were related to differences in mean annual temperature, annual precipitation, and total summer precipitation. In all of these cases, however, the increase in R^2 values over models using only DBH and height was so small that it would have no practical significance in most forestry applications. In subsequent analyses, therefore, only diameter and height were used as independent variables and regional differences were ignored.

Regression coefficients, R^2 values and standard errors for the two tree biomass models are given in Tables 10-16, and for the stump biomass model in Tables 17-23. Weight estimates for components not included in these tables are obtained using addition or subtraction of other weights following the general system of equations in Table 2.

Coefficients for the height/diameter equation are given in Table 24. This equation can be used to estimate height for estimation of the ratio (R) of merchantable stem biomass to total stem biomass.

A FORTRAN 77 subroutine was developed to handle the calculations involved in the general system of Table 2 and to facilitate the application of these biomass equations to the provincial biomass inventories and other applications (Appendix I). This subroutine was developed using the structured - design concepts described by Yourdon (1975) and others, as a relatively independent module which can be "plugged-in" to an inventory or growth modelling system with minimal interfacing problems. Documentation for the subroutine is given in the subroutine listing in Appendix I. This subroutine could easily be modified to handle additional species and/or different types of models.

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APPENDIX I

SUBROUTINE WEIGHT

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      SUBROUTINE WEIGHT(D,H,MODEL,KSP,S,T,DMIN,TOL,W,IRC)
C
C     FUNCTION: COMPUTE TREE BIOMASS COMPONENT WEIGHTS
C               FOR SEVEN MAJOR MARITIMES SPECIES
C               (BF,WS,BS,JP,RM,WB,TA) USING EQUATIONS FROM
C               ENFOR PROJECT P-159 (MFRC INFO. REP. M-X-148)
C
C     DATE:     APRIL 1983
C               REVISED OCT. 83
C
C
C     AUTHOR:   M. F. KER
C               MARITIMES FOREST RESEARCH CENTRE
C               FREDERICTON,N.B,CANADA E3B 5P7
C
C     ARGUMENTS:     D =   DBHOB (CM)
C                    H =   HEIGHT (M)
C                    MODEL = MODEL TYPE: 1 W=F(D)
C                                        2 W=F(D,H)
C                    KSP = SPECIES CODE
C                    S = STUMP HEIGHT (M)
C                    T = TOP DIAMETER INSIDE BARK (CM)
C                    DMIN = MERCHANTABLE DBHOB LIMIT (CM)
C                    TOL = ERROR  TOLERANCE (%):NEGATIVE TOP WEIGHTS
C                      CAN OCCUR FOR JACK PINE FOR STUMP HEIGHTS
C                      ABOVE 0.15 M AND DIAMETERS ABOVE 31 CM. IF THIS
C                      CONDITION OCCURS THEN STEM WEIGHTS ARE RECALCULATED
C                      USING AN AVERAGE RATIO OF TOP WEIGHT TO TOTAL
C                      ABOVEGROUND WEIGHT AS LONG AS THE NEGATIVE TOP
C                      WEIGHTS ARE WITHIN A SPECIFIED ERROR TOLERANCE
C                      LIMIT (TOL). IF THIS LIMIT IS EXCEEDED, THE RETURN
C                      CODE IRC IS SET TO 5. WITH TOL SET TO 1.0, THE
C                      SUBROUTINE DID NOT PRODUCE ANY RETURN CODES = 5
C                      IN TESTING USING A VARIETY OF TOP DIAMETERS AND
C                      STUMP HEIGHTS.
C
C                    W = TREE COMPONENT WEIGHTS (INDEXED AS IN TABLE 2)
C                    IRC = RETURN CODE : 0 = NO ERRORS DETECTED
C                                        1 = SPECIES ERROR
C                                        2 = MODEL TYPE ERROR
C                                        3 = STUMP HEIGHT OUT OF RANGE
C                                        4 = D LE T AND D GE DMIN
C                                        5 = ERROR TOLERANCE EXCEEDED
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C                                  6 = D LE 0 OR H LE 1.3
C                                  7 = FRESH WEIGHT LT DRY WEIGHT
C
C     VARIABLES:
C
C          SPECIES CODES: ISP(1) = BALSAM FIR CODE
C                         ISP(2) = WHITE SPRUCE
C                         ISP(3) = RED/BLACK SPRUCE
C                         ISP(4) = JACK PINE
C                         ISP(5) = RED MAPLE
C                         ISP(6) = WHITE BIRCH
C                         ISP(7) = ASPEN
C
C          COEFFICIENTS:
C
C              RB(I,J) = ADJUSTED SQUARED-DIAMETER RATIO
C                              METHOD (K(I) IN TABLE 3)
C               B2(I) = TAPER COEFFICIENT (P IN TABLE 3)
C               HB(I,J) = HEIGHT/DIAMETER COEFFICIENTS (TABLE 24)
C               W1(I,J) = BIOMASS COEFFICIENTS, COMPONENT 1,
C                       SPECIES I, COEFFICIENT J (MODEL 1: J = 1,2 ;
C                       MODEL 2: J = 3,...,5; STUMP BIOMASS: J=1,3)
C                       IN GENERAL, WN(I,J) CONTAINS THE COEFFICIENTS FOR
C                       COMPONENT 'N', WHERE N IS THE COMPONENT INDEX
C                       GIVEN IN TABLE 2.
C
C          PERCNT(I) = WEIGHT OF COMPONENT I AS % OF TOTAL
C                         ABOVEGROUND WEIGHT
C
      DIMENSION W(26),PERCNT(26)
      COMMON /COEFF/  RB(7,3),
     1 B2(7),HB(7,2),W1(7,5),W2(7,5),W3(7,5),
     2 W14(7,5),W15(7,5),W16(7,5),W25(7,5),W26(7,5),
     3 ISP(7),W4(7,3),W8(7,3),W17(7,3),W21(7,3)
C
C     INITIALIZE WEIGHTS
C
      DO 1 J=1,26
      W(J) = 0.0
       PERCNT(J) = 0.0
1     CONTINUE
       IRC=0
C
```

```
C     GET SPECIES INDEX K
C
       K = 0
      DO 5 I=1,7
      IF (ISP(I) .NE. KSP) GO TO 5
           K = I
           GO TO 10
5     CONTINUE
10    CONTINUE
C
C     CHECK FOR INVALID SPECIES CODE
C
      IF(K .EQ. 0) THEN
           IRC = 1
           RETURN
C
C       SET RETURN CODES FOR OUT OF RANGE CONDITIONS
C
      ELSE IF (MODEL .NE. 1 .AND. MODEL .NE. 2) THEN
           IRC = 2
           RETURN
      ELSE IF (S .EQ. 0.0 .OR. S .GT. 0.30) THEN
           IRC = 3
           RETURN
      ELSE IF ((D .GE. DMIN ) .AND. ( D .LE. T)) THEN
           IRC = 4
           RETURN
      ELSE IF (D .LE. 0.0 .OR. (H .LE. 1.3 .AND. MODEL .EQ. 2)) THEN
           IRC = 6
           RETURN
      END IF
            IF(MODEL .EQ. 1) THEN
                W(1) = W1(K,1)*D**W1(K,2)
                W(2) = W2(K,1)*D**W2(K,2)
                W(3) = W3(K,1)*D**W3(K,2)
                W(15) = W15(K,1)*D**W15(K,2)
                W(16) = W16(K,1)*D**W16(K,2)
                W(25) = W25(K,1)*D**W25(K,2)
                W(26) = W26(K,1)*D**W26(K,2)
                  H=1.3+HB(K,1)*(1.0-EXP(-HB(K,2)*D))
            ELSE
                W(1) = W1(K,3)*(D**W1(K,4))*(H**W1(K,5))
                W(2) = W2(K,3)*(D**W2(K,4))*(H**W2(K,5))
```

```
                W(3) = W3(K,3)*(D**W3(K,4))*(H**W3(K,5))
                W(15) = W15(K,3)*(D**W15(K,4))*(H**W15(K,5))
                W(16) = W16(K,3)*(D**W16(K,4))*(H**W16(K,5))
                W(25) = W25(K,3)*(D**W25(K,4))*(H**W25(K,5))
                W(26) = W26(K,3)*(D**W26(K,4))*(H**W26(K,5))
            END IF
           W(7) = W(2) - W(3)
           W(20) = W(15) - W(16)
           W(11) = W(1) - W(2)
           W(24) = W(25) + W(26)
           W(14) = W(15) + W(24)
           W(12) = W(11)*(W(25)/W(24))
           W(13) = W(11) - W(12)
            IF(D .GE. DMIN) THEN
                X=(T**2)*(1.+S/H)/((D**2)*(1.-0.04365*B2(K))**2)
                R=RB(K,1)+RB(K,2)*X+RB(K,3)*X**2
                W(4) = W4(K,1)*(D**W4(K,2))*(S**W4(K,3))
                W(5) = R*W(3)
                W(6) = W(3) - W(4) - W(5)
                W(8) = W8(K,1)*(D**W8(K,2))*(S**W8(K,3))
                W(9) = R*W(7)
                W(10) = W(7) - W(8) - W(9)
                W(17) = W17(K,1)*(D**W17(K,2))*(S**W17(K,3))
                W(18) = R*W(16)
                W(19) = W(16) - W(17) - W(18)
                W(21) = W21(K,1)*(D**W21(K,2))*(S**W21(K,3))
                W(22) = R*W(20)
                W(23) = W(20) - W(21) - W(22)
            END IF
C
C     RECALCULATE JACK PINE STEM WEIGHTS IF ANY TOP WEIGHTS
C     WERE NEGATIVE AND WITHIN ERROR TOLERANCE
C
      DO 30 J=1,26
      IF(W(J) .LT. 0.0) THEN
        IF(J .LE. 13) PERCNT(J) = 100.*ABS(W(J)/W(1))
        IF(J .GT. 13) PERCNT(J) = 100.*ABS(W(J)/W(14))
        IF(PERCNT(J) .GT. TOL) THEN
           IRC = 5
           RETURN
        END IF
          IF(J .EQ. 6 .OR. J .EQ. 19) THEN
              W(6) = 0.016*W(1)
```

```
                W(5) = W(3) - W(4) - W(6)
                W(19) = 0.016*W(14)
                W(18) = W(16) - W(17) - W(19)
            ELSE IF(J .EQ.10 .OR. J .EQ. 23) THEN
                W(10) = 0.00053*W(1)
                W(9) = W(7) - W(8) - W(10)
                W(23) = 0.00053*W(14)
                W(22) = W(20) - W(21) - W(23)
            END IF
        END IF
30      CONTINUE
               DO 55 I=1,13
               IF(W(I) .LT. W(I + 13)) IRC = 7
55              CONTINUE
        RETURN
        END
        BLOCK DATA
        COMMON /COEFF/  RB(7,3),
       1 B2(7),HB(7,2),W1(7,5),W2(7,5),W3(7,5),
       2 W14(7,5),W15(7,5),W16(7,5),W25(7,5),W26(7,5),
       3 ISP(7),W4(7,3),W8(7,3),W17(7,3),W21(7,3)
C
C       COEFFICIENTS FOR RATIO OF MERCH. STEM BIOMASS
C       TO TOTAL STEM BIOMASS USING
C       ADJUSTED SQUARED DIAMETER RATIO METHOD (TABLE 3)
C
        DATA ((RB(I,J),J=1,3),I=1,7)/
       1     0.9352,  -0.0395,  -0.8147,
       2     0.9611,   -0.2456,  -0.6801,
       3     0.9526,   -0.1027,  -0.8199,
       4     0.9604,   -0.1660,  -0.7868,
       5     0.9057,   -0.0708,  -0.8375,
       6     0.9087,   -0.3049,  -0.5107,
       7     0.9354,   0.0957,   -1.1613/
C
C       TAPER COEFFICIENTS (TABLE 3)
C
        DATA (B2(I),I=1,7)/
       1 0.152,    0.176,0.164,0.154,0.145,0.176,0.127/
C
C       HEIGHT-DIAMETER COEFFICIENTS (TABLE 24)
C
        DATA ((HB(I,J),J=1,2),I=1,7)/
```

```
     1      27.1757,   0.02632,
     2      59.8597,   0.009385,
     3      28.9866,   0.02486,
     4      21.2668,   0.04650,
     5      15.8876,   0.07780,
     6      19.9768,   0.04864,
     7      20.5601,   0.05257/
C
C      BIOMASS COEFFICIENTS (TABLES 10 - 16)
C
      DATA ((W1(I,J),J=1,5),I=1,7)/
     1      0.5157,    2.0434,    0.2419,    1.6862,    0.7175,
     2      0.2476,    2.2937,    0.2367,    2.0464,    0.3205,
     3      0.2694,    2.2548,    0.1700,    1.9597,    0.5249,
     4      0.5454,    2.0369,    0.2946,    1.8634,    0.4272,
     5      0.3496,    2.1753,    0.0769,    1.8790,    0.9183,
     6      0.3129,    2.2604,    0.1636,    1.8867,    0.6793,
     7      0.2399,    2.3236,    0.1357,    2.2104,    0.3361/
      DATA ((W2(I,J),J=1,5),I=1,7)/
     1      0.2203,    2.2010,    0.0733,    1.6955,    1.0247,
     2      0.1088,    2.4252,    0.0942,    1.6798,    0.9676,
     3      0.1504,    2.3215,    0.0657,    1.7709,    0.9674,
     4      0.3922,    2.0589,    0.0917,    1.6568,    0.9976,
     5      0.2224,    2.2166,    0.0282,    1.8128,    1.2503,
     6      0.1545,    2.3800,    0.0575,    1.7989,    1.0478,
     7      0.1744,    2.3237,    0.04601,   2.0736,    0.7681/
      DATA ((W3(I,J),J=1,5),I=1,7)/
     1      0.2124,    2.1637,    0.0705,    1.6367,    1.0520,
     2      0.0914,    2.4411,    0.0787,    1.6919,    0.9740,
     3      0.1189,    2.3545,    0.0493,    1.7800,    1.0153,
     4      0.3163,    2.0991,    0.0718,    1.6929,    1.0131,
     5      0.1779,    2.2420,    0.0213,    1.8277,    1.2848,
     6      0.1338,    2.3806,    0.0498,    1.8026,    1.0441,
     7      0.1417,    2.3273,    0.03325,   2.0565,    0.8338/
      DATA ((W14(I,J),J=1,5),I=1,7)/
     1      0.1746,    2.1555,    0.1104,    1.9209,    0.4561,
     2      0.1077,    2.3308,    0.1029,    2.0606,    0.3490,
     3      0.1444,    2.2604,    0.0884,    1.9339,    0.5740,
     4      0.2131,    2.1283,    0.1004,    1.9168,    0.5211,
     5      0.1970,    2.1933,    0.0377,    1.8706,    1.0019,
     6      0.1545,    2.3064,    0.0754,    1.8910,    0.7537,
     7      0.1049,    2.3910,    0.05533,   2.2699,    0.3703/
      DATA ((W15(I,J),J=1,5),I=1,7)/
```

```
      1      0.0671,   2.3381,   0.0286,   1.9586,   0.7794,
      2      0.0445,   2.4737,   0.0385,   1.6343,   1.0826,
      3      0.0849,   2.3130,   0.0358,   1.7073,   1.0468,
      4      0.1470,   2.1673,   0.0307,   1.7264,   1.0838,
      5      0.1351,   2.2215,   0.0150,   1.7946,   1.3264,
      6      0.0847,   2.4029,   0.0296,   1.7864,   1.1120,
      7      0.07736,  2.3971,   0.01983,  2.1551,   0.7685/
       DATA ((W16(I,J),J=1,5),I=1,7)/
      1      0.0645,   2.2962,   0.0289,   1.9157,   0.7625,
      2      0.0376,   2.4883,   0.0325,   1.6447,   1.0883,
      3      0.0690,   2.3387,   0.0275,   1.7010,   1.1058,
      4      0.1172,   2.2116,   0.0238,   1.7646,   1.1010,
      5      0.1139,   2.2342,   0.0119,   1.7964,   1.3639,
      6      0.0739,   2.3982,   0.0261,   1.7911,   1.0971,
      7      0.06392,  2.3938,   0.01511,  2.1369,   0.8147/
       DATA((W25(I,J),J=1,5),I=1,7)/
      1      0.0909,   1.8405,   0.0909,   1.8405,   0.0,
      2      0.0435,   2.1490,   0.0445,   3.0518,   -1.1236,
      3      0.0287,   2.2679,   0.0460,   2.5410,   -0.5032,
      4      0.0353,   2.1113,   0.2462,   2.7691,   -1.4849,
      5      0.0634,   2.0709,   0.0634,   2.0709,   0.0,
      6      0.0579,   2.1458,   0.0579,   2.1458,   0.0,
      7      0.01922,  2.4468,   0.06642,  2.7190,   -0.7639/
       DATA ((W26(I,J),J=1,5),I=1,7)/
      1      0.09982,   1.6421,   0.09982,   1.6421,   0.0,
      2      0.06101,  1.8465,   0.06373,  2.5314,   -0.8613,
      3      0.04949,  1.8761,   0.04949,  1.8761,   0.0,
      4      0.04892,  1.7140,   0.1875,   2.2318,   -1.1012,
      5      0.04082,  1.5518,   0.04082,  1.5518,   0.0,
      6      0.03943,  1.6286,   0.03943,  1.6286,   0.0,
      7      0.01977,  1.8031,   0.05002,  2.0766,   -0.6540/
C
C      STUMP BIOMASS COEFFICIENTS (TABLES 17 - 23)
C
       DATA ((W4(I,J),J=1,3),I=1,7)/
      1      0.08370,  1.9116,   0.9487,
      2      0.05977,  2.0442,   0.8989,
      3      0.06534,  2.0221,   0.9227,
      4      0.06236,  1.9805,   0.8941,
      5      0.06029,  2.0500,   0.9263,
      6      0.08203,  1.9812,   0.8856,
      7      0.04134,  2.0492,   0.8704/
       DATA ((W8(I,J),J=1,3),I=1,7)/
```

```
     1      0.008954, 2.0651,   0.9978,
     2      0.01046,  1.8544,   0.8161,
     3      0.03575,  1.5279,   0.8745,
     4      0.02416,  1.5235,   0.7730,
     5      0.01326,  1.8208,   0.8685,
     6      0.01784,  1.8247,   0.7885,
     7      0.02225,  1.6215,   0.6759/
      DATA ((W17(I,J),J=1,3),I=1,7)/
     1      0.02722,  2.0365,   0.9440,
     2      0.02637,  2.0848,   0.9093,
     3      0.03329,  2.0484,   0.9331,
     4      0.03229,  2.0476,   0.9607,
     5      0.03837,  2.0480,   0.9268,
     6      0.05043,  1.9955,   0.9215,
     7      0.02449,  2.0762,   0.9444/
      DATA ((W21(I,J),J=1,3),I=1,7)/
     1      0.004080, 2.1560,   1.0630,
     2      0.002706, 2.0611,   0.7707,
     3      0.01303,  1.6409,   0.8033,
     4      0.01296,  1.5630,   0.7954,
     5      0.006923, 1.8520,   0.9121,
     6      0.008852, 1.8987,   0.8127,
     7      0.01311,  1.6284,   0.7148/
C
C     SPECIES CODES, IN THE ORDER: BF,WS,BS,JP,RM,WB,TA
C
      DATA (ISP(I),I=1,7)/1,2,3,4,10,11,12/
      END
```

Table 1. Number of trees sampled by diameter class, species, and province

Province	Nova Scotia									New Brunswick										
	Species									Species										
Diameter class (cm)	bF	wS	bS	jP	rM	wB	tA	Total	%	bF	wS	bS	jP	rM	wB	tA	Total	%	Grand total	%
0 - 10	22	21	20	24	25	27	26	165	29.4	34	30	33	36	43	42	41	259	30.8	424	30.3
11 - 20	25	28	27	29	25	29	25	188	33.6	42	39	42	42	43	43	42	293	34.9	481	34.4
21 - 30	25	24	25	23	20	21	23	161	28.8	39	36	36	34	29	31	30	235	28.0	396	28.2
31 - 40	8	7	8	4	10	3	6	46	8.2	5	15	9	8	5	4	7	53	6.3	99	7.1
Total	80	80	80	80	80	80	80	560	100	120	120	120	120	120	120	120	840	100	1400	100

Table 2. A general set of additive tree biomass equations

Component	General equation			
	Fresh (green)		Ovendry	
	Index	Equation	Index	Equation
Total live above ground	1	$W_1 = f_1(D,H)$	14	$W_{14} = W_{15} + W_{24}$
1. Total bole	2	$W_2 = f_2(D,H)$	15	$W_{15} = f_{15}(D,H)$
a) Total bole wood	3	$W_3 = f_3(D,H)$	16	$W_{16} = f_{16}(D,H)$
(i) Stump wood	4	$W_4 = f_4(D,S)$	17	$W_{17} = f_{17}(D,S)$
(ii) Merchantable wood	5	$W_5 = R \cdot W_3$	18	$W_{18} = R \cdot W_{16}$
(iii) Top wood	6	$W_6 = W_3 - W_4 - W_5$	19	$W_{19} = W_{16} - W_{17} - W_{18}$
b) Total bole bark	7	$W_7 = W_2 - W_3$	20	$W_{20} = W_{15} - W_{16}$
(i) Stump bark	8	$W_8 = f_8(D,S)$	21	$W_{21} = f_{21}(D,S)$
(ii) Merchantable bark	9	$W_9 = R \cdot W_7$	22	$W_{22} = R \cdot W_{20}$
(iii) Top bark	10	$W_{10} = W_7 - W_8 - W_9$	23	$W_{23} = W_{20} - W_{21} - W_{22}$
2. Total crown	11	$W_{11} = W_1 - W_2$	24	$W_{24} = W_{25} + W_{26}$
a) Live branches	12	$W_{12} = W_{11} \cdot (W_{25}/W_{24})$	25	$W_{25} = f_{25}(D,H)$
b) Foliage	13	$W_{13} = W_{11} - W_{12}$	26	$W_{26} = f_{26}(D,H)$

where $R = k_1 + k_2X + k_3X^2$

$X = t^2D^{-2}(1-0.043\ 65\ p)^{-2}\ (1 + S/H)$

t = top diameter inside bark (cm)

D = DBHOB (cm)

f_i = regression equations (Tables 10 - 23)

S = stump height (m)

H = total height (m)

k_1, k_2, k_3 = regression coefficients (Table 3)

p = regression coefficient (Table 3)

W_i = weight (kg) of component i

Table 3. Merchantable volume conversion factor coefficients for adjusted squared diameter ratio method (from Honer *et al.*, 1983)

Species	Regression coefficients				R^2	Standard error of estimate	% Accuracy*	
	p	k_1	k_2	k_3			1	2
White pine	0.184	0.9735	-0.2348	- 0.7378	86.20	0.083	± 24.6	± 12.1
Red pine	0.151	0.9672	-0.0393	- 1.0523	89.18	0.074	± 22.5	± 10.4
Jack pine	0.151	0.9635	-0.1500	- 0.8081	88.49	0.074	± 24.4	± 11.3
Lodgepole pine	0.118	0.9658	-0.1278	- 0.8108	91.59	0.064	± 18.1	± 7.1
Black spruce	0.164	0.9526	-0.1027	- 0.8199	92.84	0.057	± 20.7	± 7.3
Red spruce	0.169	0.9644	-0.0995	- 0.7658	88.61	0.068	Not tested	
White spruce	0.176	0.9611	-0.2456	- 0.6801	91.54	0.062	± 21.9	± 7.4
Balsam fir	0.152	0.9352	-0.0395	- 0.8147	93.95	0.052	± 20.9	± 6.8
Softwoods	0.155	0.9645	-0.1616	- 0.7945	89.09	0.072	± 23.7	± 10.1
Poplar	0.127	0.9354	0.0957	- 1.1613	93.68	0.062	± 22.6	± 15.0
White birch	0.176	0.9087	-0.3049	- 0.5107	82.25	0.095	± 35.7	± 15.4
Yellow birch	0.181	0.8778	-0.2417	- 0.5247	83.32	0.089	± 39.2	± 14.0
Hardwoods	0.145	0.9057	-0.0708	- 0.8375	86.15	0.087	± 37.6	± 16.3
All species	0.154	0.9604	-0.1660	- 0.7868	88.66	0.076	± 31.1	± 13.5

*Percent accuracy: Column 1 incorporates the errors associated with the total volume equation as well as the conversion factor equation. Column 2 figures based on conversion factor errors only.

$VM_m = V_m(k_1 + k_2 X + k_3 X^2)$

where VM_m = merchantable volume; V_m = total cubic volume; $X = t_m^2 D^{-2}(1-0.043\ 65\ p)^{-2}(1+S_m/H_m)$

t_m = top diameter inside bark; D = DBHOB; S_m = stump height; H_m = total height.

Table 4. Means, standard deviations (SD), and ranges of sample tree data

Variable	Balsam fir	White spruce	Black/red spruce	Jack pine	Red maple	White birch	Trembling aspen	Softwood	Hardwood
	Species								
n	195	196	195	195	194	195	194	781	583
DBHOB (cm)									
mean	17.0	18.1	17.5	16.4	15.6	15.0	15.9	17.2	15.5
SD	9.0	9.5	9.1	8.8	9.1	8.3	9.2	9.1	8.8
range	35.6	39.3	36.6	37.6	35.2	32.8	35.9	39.3	36.0
Height (m)									
Mean	10.5	10.4	11.0	11.7	11.3	10.9	11.9	10.9	11.4
SD	4.7	4.9	4.7	4.9	4.1	4.4	4.9	4.8	4.5
range	19.6	22.2	19.6	18.9	18.7	17.9	19.2	22.2	19.4
Stump height (m)									
mean	0.15	0.15	0.15	0.10	0.15	0.15	0.13	0.14	0.14
SD	0.09	0.09	0.09	0.06	0.09	0.09	0.08	0.09	0.09
range	0.47	0.44	0.44	0.39	0.44	0.44	0.36	0.47	0.44
Stump wood volume (m^3)									
mean	0.007	0.010	0.009	0.004	0.006	0.007	0.006	0.008	0.006
SD	0.009	0.013	0.010	0.006	0.009	0.008	0.008	0.010	0.008
range	0.050	0.076	0.054	0.037	0.055	0.041	0.044	0.076	0.055
Ovendry stump wood (kg)									
mean	2.5	3.6	3.4	1.9	3.2	3.3	2.2	2.8	2.9
SD	3.2	4.7	4.2	2.5	4.4	4.2	3.0	3.8	3.9
range	16.9	26.4	21.4	15.4	27.9	20.9	16.4	26.4	27.9

Table 4. (Continued)

Fresh stump wood (kg)									
mean	5.0	7.3	6.3	3.3	5.0	5.5	3.8	5.4	4.8
SD	6.3	9.4	7.7	4.3	6.9	6.8	5.2	7.3	6.4
range	33.9	55.9	38.8	25.7	43.2	36.1	27.8	55.9	43.2
Ovendry stump bark (kg)									
mean	0.4	0.4	0.4	0.2	0.3	0.5	0.4	0.4	0.4
SD	0.7	0.5	0.5	0.3	0.4	0.7	0.5	0.5	0.5
range	5.0	3.2	2.3	1.5	2,1	4.2	2.1	5.0	4.2
Fresh stump bark (kg)									
mean	0.8	0.8	0.7	0.4	0.6	0.8	0.7	0.7	0.7
SD	1.1	0.9	0.8	0.4	0.7	1.1	0.8	0.9	0.9
range	8.1	5.5	3.6	2.5	3.8	7.3	3.9	8.1	7.3
Total fresh stem wood (kg)									
mean	131.0	158.4	142.1	147.6	125.4	126.1	134.0	144.8	128.5
SD	128.4	167.7	143.3	147.4	139.5	134.6	150.4	147.5	141.4
range	673.4	804.0	682.9	668.4	797.6	538.0	658.0	804.0	797.6
Total ovendry stemwood (kg)									
mean	60.9	75.9	78.0	78.1	78.4	73.6	75.0	73.2	75.6
SD	60.8	81.2	78.8	80.7	87.3	79.0	85.0	76.1	83.8
range	304.6	414.2	371.3	343.8	507.8	323.6	362.5	414.2	507.8
Total fresh stem bark (kg)									
mean	22.2	20.7	19.6	13.6	19.3	19.4	29.5	19.0	22.7
SD	23.0	20.6	18.0	11.8	20.6	21.1	33.0	19.0	26.0
range	124.4	109.2	85.0	51.5	120.8	90.9	168.7	124.4	168.7

Table 4. (Continued)

Total ovendry stem bark (kg)									
mean	11.6	9.9	10.4	7.0	11.0	12.1	16.9	9.7	13.3
SD	12.6	10.1	9.8	6.2	12.2	13.5	19.8	10.1	15.7
range	68.7	55.7	42.2	28.2	76.6	58.4	102.4	68.7	102.4
Total fresh stem (kg)									
mean	153.1	179.1	161.7	161.2	144.7	145.4	163.5	163.8	151.2
SD	150.9	187.8	161.0	158.8	159.6	155.1	182.9	165.2	166.2
range	797.8	913.2	755.1	712.1	900.5	623.0	826.7	913.2	900.5
Total ovendry stem (kg)									
mean	72.5	85.7	88.5	85.1	89.4	85.6	91.7	83.0	88.9
SD	73.0	91.2	88.4	86.7	99.1	92.0	104.5	85.2	98.5
range	373.4	470.0	403.4	361.9	566.4	375.8	456.5	470.0	566.4
Fresh dead Branches (kg)									
mean	6.7	6.9	7.9	7.5	4.4	2.5	4.0	7.3	3.6
SD	16.3	10.3	11.6	12.5	10.2	10.0	10.8	12.8	10.4
range	209.6	67.9	91.3	102.2	125.1	129.5	129.0	209.6	129.5
Ovendry dead branches (kg)									
mean	5.3	5.5	6.2	6.0	3.3	1.6	3.0	5.8	2.6
SD	12.8	8.2	9.2	10.1	7.7	6.4	8.0	10.2	7.4
range	164.3	54.0	72.4	82.3	94.1	83.1	96.0	164.3	96.0
Total fresh crown live (kg)									
mean	63.8	87.6	72.5	47.9	53.8	57.4	60.1	68.0	57.1
SD	61.2	87.2	72.4	52.0	61.8	59.8	72.0	70.8	64.7
range	276.8	500.1	332.1	231.4	317.4	294.3	345.2	500.4	345.2

Table 4. (Continued)

Total ovendry crown (kg)									
mean	32.3	45.0	39.0	23.9	29.1	29.8	29.6	35.1	29.5
SD	31.3	45.5	39.5	26.3	34.1	32.0	36.1	37.2	34.0
range	140.6	260.3	182.3	115.9	174.6	159.6	170.8	260.5	174.6
Ovendry branch (kg)									
mean	20.2	29.3	26.1	17.0	25.7	26.1	26.0	23.2	25.9
SD	20.3	31.1	27.7	19.7	31.0	29.0	32.7	25.6	30.9
range	89.1	177.7	131.1	84.0	158.1	147.5	151.3	177.8	158.1
Ovendry foliage (kg)									
mean	12.1	15.7	13.0	6.9	3.4	3.7	3.6	11.9	3.6
SD	11.0	14.5	11.9	6.7	3.2	3.2	3.6	11.8	3.3
range	51.5	82.6	51.2	31.9	16.5	13.6	19.5	82.7	19.5
Fresh total above ground (kg)									
mean	217.0	266.7	234.2	209.2	198.4	203.0	223.6	231.8	208.3
SD	204.0	266.7	227.9	204.8	216.0	209.2	247.6	228.0	224.7
range	934.0	1223.7	1087.2	876.7	1081.2	824.6	1063.8	1223.8	1081.2
Ovendry total above ground (kg)									
mean	104.8	130.7	127.5	109.0	118.5	115.4	121.3	118.0	118.4
SD	99.8	131.6	124.5	109.3	130.0	120.8	136.9	117.3	129.2
range	443.2	589.1	575.5	435.2	663.2	495.2	584.7	589.1	663.2

Table 5. Mean ovendry component weights as percentage of mean total ovendry weight

Component	Species							Softwood	Hardwood
	Balsam fir	White spruce	Black/red spruce	Jack pine	Red maple	White birch	Aspen		
Stem wood	58.1	58.0	61.2	71.6	66.1	63.7	61.7	62.0	63.8
Stem bark	11.1	7.6	8.2	6.5	9.3	10.5	13.9	8.3	11.3
Total stem	69.2	65.6	69.4	78.1	75.4	74.2	75.6	70.3	75.1
Stump wood	2.4	2.7	2.7	1.7	2.7	2.9	1.8	2.4	2.5
Stump bark	0.4	0.3	0.3	0.2	0.3	0.4	0.3	0.3	0.3
Total stump	2.8	3.0	3.0	1.9	3.0	3.3	2.1	2.7	2.8
Live branches	19.3	22.4	20.4	15.6	21.8	22.6	21.4	19.6	21.9
Foliage	11.5	12.0	10.2	6.3	2.8	3.2	3.0	10.1	3.0
Total live crown	30.8	34.4	30.6	21.9	24.6	25.8	24.4	29.7	24.9
Total above ground	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6. Mean ovendry component weights as a percentage of mean ovendry stem wood weight

Component	Species							Softwood	Hardwood
	Balsam fir	White spruce	Black/red spruce	Jack pine	Red maple	White birch	Aspen		
Stem wood	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Stem bark	19.0	13.0	13.4	9.0	14.1	16.4	22.5	13.3	17.6
Total stem	119.0	113.0	113.4	109.0	114.1	116.4	122.5	113.3	117.6
Stump wood	4.1	4.7	4.4	2.4	4.1	4.5	3.0	3.9	3.8
Stump bark	0.7	0.6	0.6	0.3	0.4	0.7	0.5	0.5	0.5
Total stump	4.8	5.3	5.0	2.7	4.5	5.2	3.5	4.4	4.4
Dead branches	8.7	7.3	8.0	7.7	4.2	2.2	4.0	7.9	3.5
Total crown	53.0	59.3	50.0	30.6	37.1	40.5	39.5	47.9	39.0
Total above ground	172.0	172.3	163.4	139.6	151.2	156.9	162.0	161.2	156.6

Table 7. Ratio of ovendry weight of foliage to total fresh branch weight, based on ratio of means estimator ($\Sigma y/\Sigma x$) and 4734 branch samples

	Species						
Crown stratum[1]	Balsam fir	White spruce	Black spruce	Jack pine	Red maple	White birch	Trembling aspen
1	0.226	0.228	0.219	0.190	0.143	0.123	0.128
3	0.179	0.176	0.177	0.147	0	0	0
5	0.115	0.133	0.135	0.117	0	0	0
7	0.159	0.077	0.117	0.095	0	0	0
9	0.164	-	-	0.088	0	0	0
11	-	-	-	-	0	0	0
13	-	-	-	-	0	0	0
15	-	-	-	-	0	0	0
17	-	-	-	-	0	0	0
19	-	-	-	-	0	0	0

[1] Midpoint of branch size class in centimetres.

Table 8. Ratio of ovendry weight of branch wood and bark to total fresh branch weight, based on ratio of means estimator ($\Sigma y/\Sigma x$) and 4734 branch samples

Crown Stratum[1]	Balsam fir	White spruce	Black spruce	Jack pine	Red maple	White birch	Trembling aspen
	Species						
Dead	0.784	0.795	0.793	0.805	0.752	0.642	0.744
1	0.262	0.264	0.299	0.290	0.339	0.341	0.318
3	0.333	0.336	0.364	0.348	0.582	0.575	0.520
5	0.420	0.410	0.421	0.394	0.587	0.583	0.533
7	0.406	0.491	0.443	0.419	0.587	0.578	0.543
9	0.328	-	-	0.452	0.595	0.585	0.553
11	-	-	-	-	0.600	0.588	0.558
13	-	-	-	-	0.614	0.584	0.564
15	-	-	-	-	0.592	0.612	0.595
17	-	-	-	-	0.588	-	-
19	-	-	-	-	0.579	-	-

[1] Midpoint of branch size class in centimetres.

Table 9. Ratio of mean ovendry weight to mean fresh weight by species and component

Component	Species							Softwood	Hardwood
	Balsam fir	White spruce	Black/red spruce	Jack pine	Red maple	White birch	Aspen		
Stem wood	0.465	0.479	0.549	0.529	0.625	0.584	0.559	0.506	0.588
Stem bark	0.523	0.476	0.532	0.516	0.572	0.622	0.573	0.511	0.587
Total stem	0.474	0.479	0.547	0.528	0.618	0.589	0.561	0.506	0.588
Stump wood	0.494	0.493	0.546	0.565	0.639	0.610	0.580	0.519	0.612
Stump bark	0.556	0.549	0.583	0.581	0.546	0.603	0.563	0.565	0.573
Total stump	0.503	0.498	0.550	0.579	0.629	0.609	0.577	0.524	0.607
Dead branches	0.784	0.795	0.793	0.567	0.752	0.642	0.744	0.795	0.723
Total crown	0.506	0.514	0.538	0.498	0.541	0.519	0.492	0.516	0.516
Total above ground	0.483	0.490	0.544	0.521	0.597	0.569	0.543	0.509	0.568

Table 10. Biomass equations[1] for balsam fir (See also table 2)

Component			Model 1: $W = aD^b$				Model 2: $W = aD^b H^c$				
Index	Name	N	a	b	R^2	S.E.E.	a	b	c	R^2	S.E.E.
1	Total live Above ground (fresh)	198	0.5157	2.0434	0.968	54.4	0.2419	1.6862	0.7175	0.980	43.3
2	Total bole (fresh)	198	0.2203	2.2010	0.969	38.5	0.0733	1.6955	1.0247	0.993	18.8
3	Total bole wood (fresh)	198	0.2124	2.1637	0.967	33.9	0.0705	1.6367	1.0520	0.992	17.0
14	Total live Above ground (ovendry)	196	0.1746	2.1555	0.982	19.6	0.1104	1.9209	0.4561	0.987	17.0
15	Total bole (ovendry)	198	0.0671	2.3381	0.978	15.4	0.0286	1.9586	0.7794	0.992	9.3
16	Total bole wood (ovendry)	198	0.0645	2.2962	0.979	12.8	0.0289	1.9157	0.7625	0.992	7.8
25	Branches (ovendry)	196	0.0909	1.8405	0.857	10.9	-	-	-	-	-
26	Foliage (ovendry)	196	0.09982	1.6421	0.848	0.08[2]	-	-	-	-	-

[1] W = weight (kg); D = diameter at 1.30 m outside bark (cm); H = total height (m).

[2] Weighted regression.

Table 11. Biomass equations[1] for white spruce (see also table 2)

Component			Model 1: $W = aD^b$				Model 2: $W = aD^bH^c$				
Index	Name	N	a	b	R^2	S.E.E.	a	b	c	R^2	S.E.E.
1	Total live above ground (fresh)	197	0.2476	2.2937	0.972	63.0	0.2367	2.0464	0.3205	0.974	61.4
2	Total bole (fresh)	197	0.1088	2.4252	0.972	43.9	0.0942	1.6798	0.9676	0.985	32.0
3	Total bole wood (fresh)	197	0.0914	2.4411	0.969	41.0	0.0787	1.6919	0.9740	0.982	30.9
14	Total live above ground (ovendry)	197	0.1077	2.3308	0.978	27.5	0.1029	2.0606	0.3490	0.980	26.4
15	Total bole (ovendry)	197	0.0445	2.4737	0.974	20.1	0.0385	1.6343	1.0826	0.991	12.0
16	Total bole wood (ovendry)	197	0.0376	2.4883	0.974	17.9	0.0325	1.6447	1.0883	0.991	10.7
25	Branches (ovendry)	197	0.0435	2.1490	0.873	15.3	0.0445	3.0518	-1.1236	0.892	14.2
26	Foliage (ovendry)	197	0.06101	1.8465	0.900	6.8	0.06373	2.5314	-0.8613	0.911	6.4

[1]W = weight (kg); D = diameter at 1.30 m outside bark (cm); H = total height (m).

Table 12. Biomass equations[1] for red/black spruce (see also table 2)

Component			Model 1: $W = aD^b$				Model 2: $W = aD^b H^c$				
Index	Name	N	a	b	R^2	S.E.E.	a	b	c	R^2	S.E.E.
1	Total live above ground (fresh)	195	0.2694	2.2548	0.975	51.8	0.1700	1.9597	0.5249	0.979	47.5
2	Total bole (fresh)	195	0.1504	2.3215	0.975	36.0	0.0657	1.7709	0.9674	0.989	24.2
3	Total bole wood (fresh)	195	0.1189	2.3545	0.973	33.6	0.0493	1.7800	1.0153	0.987	22.8
14	Total live above ground (ovendry)	195	0.1444	2.2604	0.978	26.2	0.0884	1.9339	0.5740	0.983	23.1
15	Total bole (ovendry)	195	0.0849	2.3130	0.976	19.3	0.0358	1.7073	1.0468	0.992	11.2
16	Total bole wood (ovendry)	195	0.0690	2.3387	0.974	18.1	0.0275	1.7010	1.1058	0.991	10.7
25	Branches (ovendry)	195	0.0287	2.2679	0.895	12.4	0.0460	2.5410	-0.5032	0.898	12.2
26	Foliage (ovendry)	195	0.04949	1.8761	0.910	5.3	-	-	-	-	-

[1] W = weight (kg); D = diameter at 1.30 m outside bark (cm); H = total height (m).

Table 13. Biomass equations[1] for jack pine (see also table 2)

Component			Model 1: $W = aD^{b}$				Model 2: $W = aD^{b}H^{c}$				
Index	Name	N	a	b	R^2	S.E.E.	a	b	c	R^2	S.E.E.
1	Total live above ground (fresh)	195	0.5454	2.0369	0.973	48.2	0.2946	1.8634	0.4272	0.975	46.3
2	Total bole (fresh)	195	0.3922	2.0589	0.973	37.2	0.0917	1.6568	0.9976	0.985	27.7
3	Total bole wood (fresh)	195	0.3163	2.0991	0.972	34.9	0.0718	1.6929	1.0131	0.984	26.3
14	Total live above ground (ovendry)	195	0.2131	2.1283	0.978	23.2	0.1004	1.9168	0.5211	0.981	21.5
15	Total bole (ovendry)	195	0.1470	2.1673	0.972	20.5	0.0307	1.7264	1.0838	0.986	14.6
16	Total bole wood (ovendry)	195	0.1172	2.2116	0.971	19.3	0.0238	1.7646	1.1010	0.985	14.0
25	Branches (ovendry)	195	0.0353	2.1113	0.845	10.3	0.2462	2.7691	-1.4849	0.873	9.3
26	Foliage (ovendry)	195	0.04892	1.7140	0.870	3.5	0.1875	2.2318	-1.1012	0.888	3.2

[1] W = weight (kg); D = diameter at 1.30 m outside bark (cm); H = total height (m).

Table 14. Biomass equations[1] for red maple (see also table 2)

Component			Model 1: $W = aD^b$				Model 2: $W = aD^bH^c$				
Index	Name	N	a	b	R^2	S.E.E.	a	b	c	R^2	S.E.E.
1	Total live above ground (fresh)	198	0.3496	2.1753	0.967	55.5	0.0769	1.8790	0.9183	0.978	45.0
2	Total bole (fresh)	198	0.2224	2.2166	0.965	41.4	0.0282	1.8128	1.2503	0.987	25.8
3	Total bole wood (fresh)	198	0.1779	2.2420	0.964	36.8	0.0213	1.8277	1.2848	0.986	22.7
14	Total live above ground (ovendry)	198	0.1970	2.1933	0.965	34.0	0.0377	1.8706	1.0019	0.979	26.5
15	Total bole (ovendry)	198	0.1351	2.2215	0.962	26.9	0.0150	1.7946	1.3264	0.986	16.4
16	Total bole wood (ovendry)	198	0.1139	2.2342	0.961	23.9	0.0119	1.7964	1.3639	0.986	14.3
25	Branches (ovendry)	197	0.0634	2.0709	0.868	14.8	-	-	-	-	-
26	Foliage (ovendry)	197	0.04082	1.5518	0.879	1.6	-	-	-	-	-

[1] W = weight (kg); D = diameter at 1.30 m outside bark (cm); H = total height (m).

Table 15. Biomass equations[1] for white birch (see also table 2)

Component			Model 1: $W = aD^b$				Model 2: $W = aD^bH^c$				
Index	Name	N	a	b	R^2	S.E.E.	a	b	c	R^2	S.E.E.
1	Total live above ground (fresh)	196	0.3129	2.2604	0.981	40.6	0.1636	1.8867	0.6793	0.988	31.6
2	Total bole (fresh)	196	0.1545	2.3800	0.975	33.6	0.0575	1.7989	1.0478	0.992	19.4
3	Total bole wood (fresh)	196	0.1338	2.3806	0.976	28.7	0.0498	1.8026	1.0441	0.992	16.1
14	Total live above ground (ovendry)	196	0.1545	2.3064	0.978	24.5	0.0754	1.8910	0.7537	0.988	18.5
15	Total bole (ovendry)	196	0.0847	2.4029	0.973	20.6	0.0296	1.7864	1.1120	0.992	11.5
16	Total bole wood (ovendry)	196	0.0739	2.3982	0.974	17.5	0.0261	1.7911	1.0971	0.992	9.6
25	Branches (ovendry)	196	0.0579	2.1458	0.892	12.8	-	-	-	-	-
26	Foliage (ovendry)	196	0.03943	1.6286	0.861	0.03[2]	-	-	-	-	-

[1] W = weight (kg); D = diameter at 1.30 m outside bark (cm); H = total height (m).

[2] Weighted regression.

Table 16. Biomass equations[1] for trembling aspen (see also table 2)

Component			Model 1: $W = aD^b$				Model 2: $W = aD^bH^c$				
Index	Name	N	a	b	R^2	S.E.E.	a	b	c	R^2	S.E.E.
1	Total live above ground (fresh)	197	0.2399	2.3236	0.989	35.6	0.1357	2.2104	0.3361	0.990	33.6
2	Total bole (fresh)	197	0.1744	2.3237	0.986	29.5	0.04601	2.0736	0.7681	0.992	21.9
3	Total bole wood (fresh)	197	0.1417	2.3273	0.985	24.7	0.03325	2.0565	0.8338	0.993	17.4
14	Total live above ground (ovendry)	197	0.1049	2.3910	0.989	19.5	0.05533	2.2699	0.3703	0.991	18.1
15	Total bole (ovendry)	197	0.07736	2.3971	0.986	16.8	0.01983	2.1551	0.7685	0.992	12.5
16	Total bole wood (ovendry)	197	0.06392	2.3938	0.986	13.6	0.01511	2.1369	0.8147	0.993	9.6
25	Branches (ovendry)	197	0.01922	2.4468	0.872	15.8	0.06642	2.7190	-0.7639	0.878	15.5
26	Foliage (ovendry)	197	0.01977	1.8031	0.874	1.9	0.05002	2.0766	-0.6540	0.880	1.8

[1] W = weight (kg); D = diameter at 1.30 m outside bark (cm); H = total height (m).

Table 17. Stump biomass equations[1] for balsam fir

Component			General equation: $W = aD^bS^c$				
Index	Name	N	a	b	c	R^2	S.E.E.
4	Fresh stump wood	196	0.08370	1.9116	0.9487	0.991	0.82
8	Fresh stump bark	196	0.008954	2.0651	0.9978	0.949	0.023[2]
17	Ovendry stump wood	196	0.02722	2.0365	0.9440	0.999	0.0022[2]
21	Ovendry stump bark	196	0.004080	2.1560	1.0630	0.934	0.014[2]

[1]W = weight (kg); D = diameter breast height outside bark (cm); S = stump height (m).
[2]Weighted regression.

Table 18. Stump biomass equations[1] for white spruce

Component			General equation: $W = aD^bS^c$				
Index	Name	N	a	b	c	R^2	S.E.E.
4	Fresh stump wood	197	0.05977	2.0442	0.8989	0.986	1.44
8	Fresh stump bark	197	0.01046	1.8544	0.8161	0.964	0.24
17	Ovendry stump wood	197	0.02637	2.0848	0.9093	0.999	0.0048[2]
21	Ovendry stump bark	197	0.002706	2.0611	0.7707	0.951	0.16

[1]W = weight (kg); D = diameter breast height outside bark (cm); S = stump height (m).
[2]weighted regression.

Table 19. Stump biomass equations[1] for red/black spruce

Component			General equation: $W = aD^bS^c$				
Index	Name	N	a	b	c	R^2	S.E.E.
4	Fresh stump wood	195	0.06534	2.0221	0.9227	0.989	1.03
8	Fresh stump bark	195	0.03575	1.5279	0.8745	0.961	0.22
17	Ovendry stump wood	195	0.03329	2.0484	0.9331	0.999	0.0031[2]
21	Ovendry stump bark	195	0.01303	1.6409	0.8033	0.954	0.14

[1] W = weight (kg); D = diameter breast height outside bark (cm); S = stump height (m).
[2] Weighted regression.

Table 20. Stump biomass equations[1] for jack pine

Component			General Equation: $W = aD^bS^c$				
Index	Name	N	a	b	c	R^2	S.E.E.
4	Fresh stump wood	195	0.06236	1.9805	0.8941	0.995	0.40
8	Fresh stump bark	195	0.02416	1.5235	0.7730	0.934	0.15
17	Ovendry stump wood	195	0.03229	2.0476	0.9607	0.999	0.0023[2]
21	Ovendry stump bark	195	0.01296	1.5630	0.7954	0.925	0.093

[1] W = weight (kg); D = diameter breast height outside bark (cm); S = stump height (m).
[2] Weighted regression.

Table 21. Stump biomass equations[1] for red maple

Component			General equation: $W = aD^bS^c$				
Index	Name	N	a	b	c	R^2	S.E.E.
4	Fresh stump wood	197	0.06029	2.0500	0.9263	0.998	0.49
8	Fresh stump bark	197	0.01326	1.8208	0.8685	0.949	0.28
17	Ovendry stump wood	197	0.03837	2.0480	0.9268	0.999	0.0060[2]
21	Ovendry stump bark	197	0.006923	1.8520	0.9121	0.954	0.15

[1] W = weight (kg); D = diameter breast height outside bark (cm); S = stump height (m).
[2] Weighted regression.

Table 22. Stump biomass equations[1] for white birch

Component			General equation: $W = aD^bS^c$				
Index	Name	N	a	b	c	R^2	S.E.E.
4	Fresh stump wood	196	0.08203	1.9812	0.8856	0.996	0.53
8	Fresh stump bark	196	0.01784	1.8247	0.7885	0.873	0.50
17	Ovendry stump wood	196	0.05043	1.9955	0.9215	0.999	0.02
21	Ovendry stump bark	196	0.008852	1.8987	0.8127	0.886	0.29

[1] W = weight (kg); D = diameter breast height outside bark (cm); S = stump height (m).

Table 23. Stump biomass equations[1] for trembling aspen

Component			General equation: $W = aD^bS^c$				
Index	Name	N	a	b	c	R^2	S.E.E.
4	Fresh stump wood	198	0.04134	2.0492	0.8704	0.997	0.42
8	Fresh stump bark	197	0.02225	1.6215	0.6759	0.960	0.23
17	Ovendry stump wood	197	0.02449	2.0762	0.9444	0.999	0.0030[2]
21	Ovendry stump bark	197	0.01311	1.6284	0.7148	0.956	0.14

[1] W = weight (kg); D = diameter breast height outside bark (cm); S = stump height (m)

[2] weighted regression

Table 24. Height/diameter equations[1] for seven major Maritimes tree species

Species	General equation: $H = 1.3 + a (1 - \exp(-bD))$				
	n	a	b	R^2	S.E.E.
Balsam fir	196	27.1757	0.02632	0.978	1.72
White spruce	197	59.8597	0.009385	0.978	1.71
Red/black spruce	195	28.9866	0.02486	0.983	1.58
Jack pine	195	21.2668	0.04650	0.975	2.01
Red maple	197	15.8876	0.07780	0.983	1.59
White birch	196	19.9768	0.04864	0.980	1.67
Trembling aspen	197	20.5601	0.05257	0.983	1.70
Softwood	781	26.6095	0.02809	0.974	1.94
Hardwood	592	18.5305	0.05842	0.980	1.72

[1] H = height (m); D = diameter outside bark (cm) at 1.3 m.

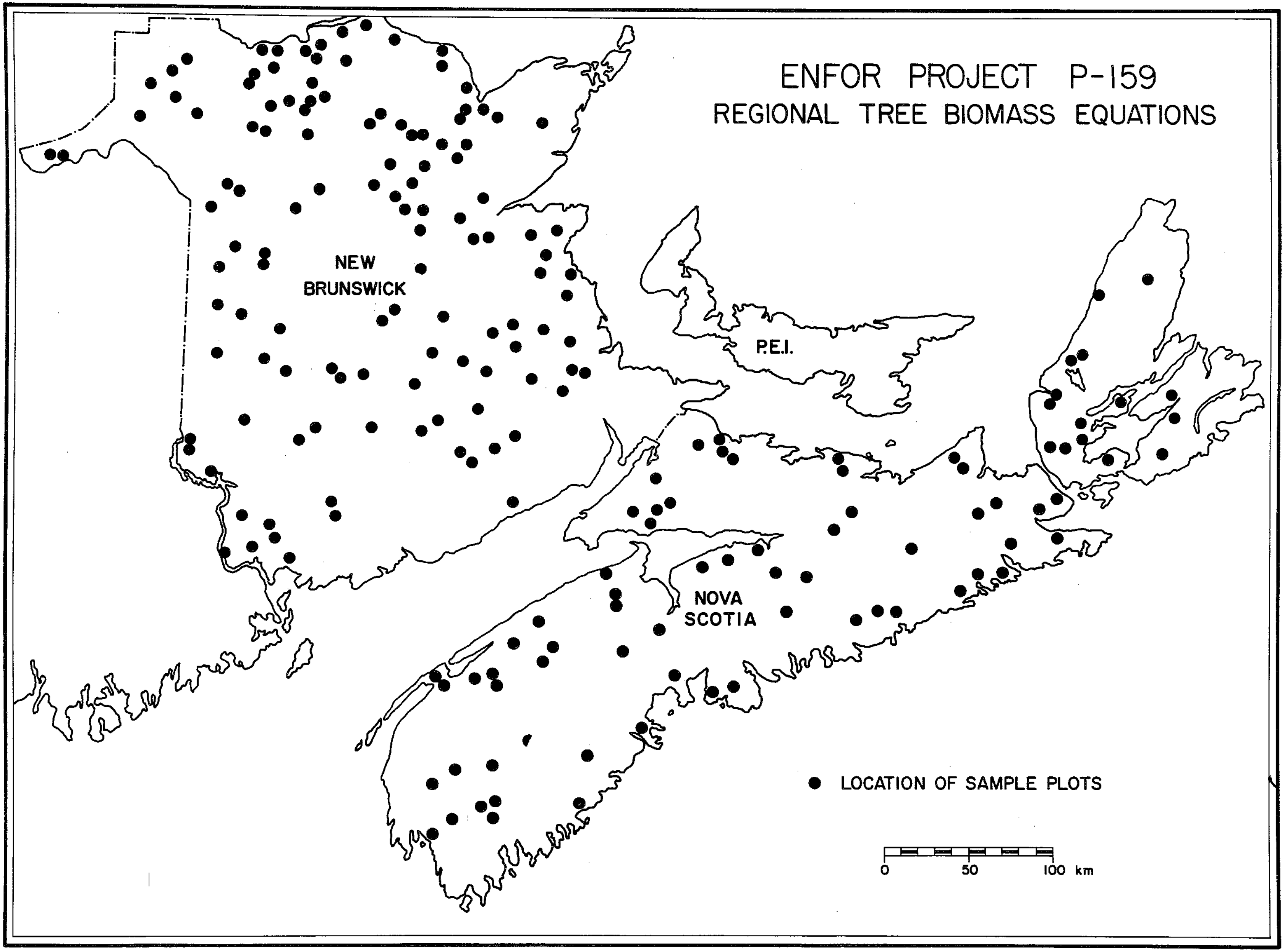

Figure 1. Location of sample plots

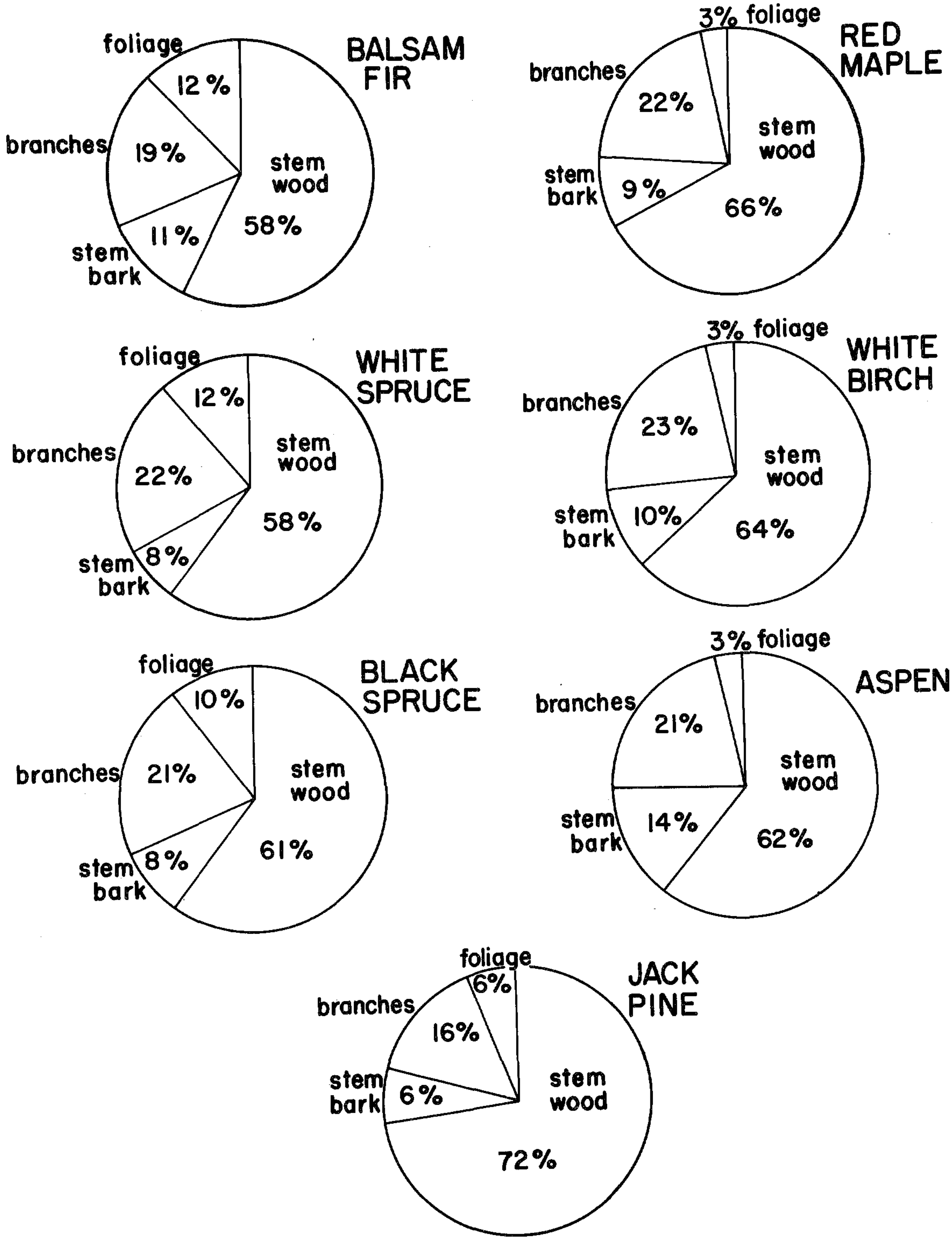

Figure 2. Distribution of total aboveground biomass for seven Maritimes species, based on mean ovendry weights of each component.