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Hubbard Brook Experimental Forest**



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# Notes and Comments

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## CORRECTIONS TO ALLOMETRIC EQUATIONS AND PLANT TISSUE CHEMISTRY FOR HUBBARD BROOK EXPERIMENTAL FOREST

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The allometric equations (Whittaker et al. 1974) and plant tissue chemistry (Likens and Bormann 1970, Whittaker et al. 1979) reported for the Hubbard Brook Experimental Forest (HBEF) in New Hampshire have proven valuable, not only for our own long-term studies of forest productivity and nutrient cycling (Likens et al. 1977, Bormann and Likens 1979, Likens 1985), but also to other researchers in similar forests (Morrison 1990, Aber et al. 1991, Burton et al. 1991) and to those making comparisons (Hogan and Morrison 1988). However, there are several errors in and additions to the published allometric equations and nutrient concentrations. It is important for anyone using these equations and concentrations to be aware of these errors and additions. In some cases, these errors have led to incorrect use of the equations (Martin 1977, Eickmeier 1988, Onega and Eickmeier 1991).

The recent whole-tree harvest at the HBEF (1983–1984) provided an opportunity to validate these allometric equations. When applied in the manner designed and intended by Whittaker et al. (1974), we found that they closely predict measured biomass. Although these equations have been used most often with diameter at breast height (dbh) as the only independent variable (Johannes et al. 1986, Cronan et al. 1987, Melancon and Lechowicz 1987), we found that equations based on parabolic volume (PV), which take tree height into account, are much better predictors than dbh alone.

### Allometric Equations (Whittaker et al. 1974)

There are errors in column headings of tables in Whittaker et al. (1974) that will result in the equations

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being used inappropriately. The dependent variables, **Aboveground dry weight, g:** and **Log, aboveground dry weight, g:** in Tables 2 and 3 (Whittaker et al. 1974) are mislabeled. They should read *Total dry mass in grams:* and *Log, total dry mass in grams:*, representing in reality the sum of aboveground plus belowground dry mass. The belowground mass of the species referred to in the tables is 14–20% of the total dry mass; thus use of the mislabeled equations leads to an overestimate of aboveground biomass of a northern hardwood forest by that amount. Correct equations for aboveground biomass for the four species are as follows:

### Sugar maple (*Acer saccharum*)

$$\begin{aligned}\log_{10}(\text{aboveground dry mass in grams}) &= 2.0537 + 2.4793 \log_{10}(\text{dbh in centimetres}) \\ \log_{10}(\text{aboveground dry mass in grams}) &= -0.0201 + 0.9768 \log_{10}(\text{PV in cubic centimetres})\end{aligned}$$

### Beech (*Fagus grandifolia*)

$$\begin{aligned}\log_{10}(\text{aboveground dry mass in grams}) &= 2.1112 + 2.4620 \log_{10}(\text{dbh in centimetres}) \\ \log_{10}(\text{aboveground dry mass in grams}) &= 0.1733 + 0.9526 \log_{10}(\text{PV in cubic centimetres})\end{aligned}$$

### Yellow birch (*Betula alleghaniensis*); (referred to as *B. lutea* in Whittaker et al. 1974)

$$\begin{aligned}\log_{10}(\text{aboveground dry mass in grams}) &= 2.1047 + 2.4417 \log_{10}(\text{dbh in centimetres}) \\ \log_{10}(\text{aboveground dry mass in grams}) &= 0.0974 + 0.9615 \log_{10}(\text{PV in cubic centimetres})\end{aligned}$$

### Red spruce (*Picea rubens*)

$$\begin{aligned}\log_{10}(\text{aboveground dry mass in grams}) &= 2.1735 + 2.1936 \log_{10}(\text{dbh in centimetres}) \\ \log_{10}(\text{aboveground dry mass in grams}) &= 0.8219 + 0.7966 \log_{10}(\text{PV in cubic centimetres}).\end{aligned}$$

We have reviewed the original data from which the allometric equations presented by Whittaker et al. (1974) were developed. The coefficients are correct as published; the problem is limited to mislabeling in the publishing of the tables. The published biomass and nutrient estimates for watershed six (W 6) of the HBEF (Whittaker et al. 1974, 1979) were not affected by this error.

The heading in Table 4, subsection F (Whittaker et al. 1974) **Regression predictions: Biomass aboveground, t/ha** [i.e., Mg/ha], is the projected maximum standing crop biomass at steady state for W 6 as determined by the current productivity. These values are not the biomass on the watershed in 1965. The 1965 biomass on W 6 is given in subsection D of Table 4.

*Biomass of Spruce Needles (Whittaker et al. 1974)*

Although not an error as such, the equations in Tables 2 and 3 for biomass of red spruce needles (**current twig and leaf production, g/yr:** and **Log current twig and leaf production g/yr:**) are for current needles and twigs only (Whittaker et al. 1974). No equations for older needles were presented, although the mass of older needles was determined in the original dimension analysis. Because of the recent interest in red spruce decline in the northeastern U.S. (e.g., Friedland et al. 1991) it is important to remind users that the published equations are for current twigs and needles only. The equations for older needles, based on both dbh and parabolic volume (PV), are given below:

$$\begin{aligned} \log_{10}(\text{older needle mass in grams}) \\ &= 1.6119 + 1.6991 \log_{10}(\text{dbh in centimetres}) \\ \log_{10}(\text{older needle mass in grams}) \\ &= 0.5764 + 0.6164 \log_{10}(\text{PV in cubic centimetres}). \end{aligned}$$

Either one of these equations, together with the published equations for current twigs and needles (Whittaker et al. 1974) will give the total needle mass plus twig mass for red spruce in the northern hardwood forest. Current needle/twig ratios were not given in Table 1 of Whittaker et al. (1974). We have calculated current needles alone to be 79% of the dry mass of the needle plus twig masses estimated by the equation.

*Mountain Maple (Whittaker et al. 1974)*

We believe that the equations for mountain maple (*Acer spicatum*) as reported in Tables 2 and 3 of Whittaker et al. (1974) instead may be for striped maple (*Acer pennsylvanicum*). Our support for this conclusion is that the original dimension analysis data include stems of unreasonable diameters and heights for mountain maple. Mountain maple is a shrub, usually 2 or 3 m tall with commonly occurring diameters of 4–5 cm (although certainly larger sizes are known at the HBEF). In the original dimension analysis data for this species Whittaker et al. (1974) analyzed stems 10 cm in dbh and 10 m tall. Thus, it is our opinion that these equations should be used with caution. At the HBEF these species are of very minor abundance and contribute very little (<1%) to the total biomass. Thus we have not provided a corrected aboveground biomass estimator equation for this species.

*Plant Tissue Chemistry*

The concentration of phosphorus in roots (0.37%) recorded for sugar maple by Whittaker et al. (1979), and Likens and Bormann (1970), appears high in comparison with P concentrations in the other parts of this species and with other species, including the congener, mountain maple. More recent analyses (Fahey et al. 1988, Yanai 1990) indicate that P concentrations are

≈ 1/10 of the Whittaker et al. (1979) values. Thus, we suggest that 0.04% is more representative of P concentrations in sugar maple roots for the HBEF (Fahey et al. 1988, Yanai 1990). Recalculation of the phosphorus content in the biomass of sugar maple roots on W 6 in 1965 using the lower value results in a reduction of estimated P content of sugar maple roots from 34.7 kg/ha to 4.1 kg/ha, and for the total biomass of all species the reported phosphorus value of 88 kg/ha in Whittaker et al. (1979) should be 56 kg/ha.

*Comparison of Two Estimates of Forest Biomass at the HBEF*

The harvesting of watershed 5 in 1983–1984 as part of an experimental whole-tree harvest treatment provided an opportunity to compare estimates of biomass using allometry with results of actual weighing of total aboveground biomass. Total forest living biomass was estimated on three 0.25-ha plots using a total stem inventory (≥ 10 cm dbh) and the allometric equations (Whittaker et al. 1974) based on parabolic volume (PV). Tree heights in 1983, needed to calculate PV, were obtained from standing and felled trees at the time of the cut (winter of 1983–1984). Tree diameter to height relationships had changed significantly since the original tree height measurements in 1965, with trees of a given diameter being much taller (3–4 m) in 1983 than a tree of the same diameter in 1965.

Trees from the three 0.25-ha plots were felled, chipped into semi-trailer vans and weighed separately for each plot. Chips blown into vans were sampled (Hornbeck and Kropelin 1983) for wet/dry mass conversion and the vans were weighed to get total biomass. Logs selected for timber were sampled from freshly cut ends for wet/dry mass conversion and weighed on the trucks.

Slash remaining on the watershed after the cut was sampled by size classes on  $N = 27$  10 × 10 m plots, and on  $N = 108$  2 × 2 m and 1 × 1 m plots to estimate amounts of material present on the plots that would have been included in the allometry estimates, but which was not weighed in the harvesting process;  $19 \pm 2.4$  Mg/ha of tree debris (mostly broken-off branches of various sizes) were left on the watershed. Since the plots harvested for biomass comparison were monitored carefully during clearing and skidding, less than the watershed average of 19 Mg/ha was left on these plots, but these plots were not sampled separately for slash.

The comparative results for the three plots are summarized in Table 1. Estimates based on allometry were ≈ 12 Mg/ha higher than the weighed amount. However when the weighed amounts are corrected for slash, that is increased by ≈ 50–75% of what was the average slash for the watershed as a whole (50–75% because of the care with which the biomass plots were harvested), the

TABLE 1. Weighed aboveground biomass on each of three 0.25-ha plots, in comparison with aboveground biomass estimated by allometry, in the northern hardwood forest at Hubbard Brook Experimental Forest (HBEF) in 1983–1984.

Plot	Biomass (Mg/ha)			Estimate by allometry
	Measured value			
	Chips	Logs	Total	
Blue	120.5	28.5	149	176
White	167.2	28.0	195	215
Green	164.1	32.9	197	186
Mean			180	192
Estimated slash (Mg/ha)			9–14	
Total (Mg/ha)			189–194	

comparison shows an excellent predictability of the Hubbard Brook allometric equations when linked to changing tree diameter to height ratios. These results provide a strong verification of the use of allometric equations developed by Whittaker et al. (1974) in the northern hardwood forest.

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