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Methods to Estimate Total Forest Biomass for Extensive Forest Inventories:

Applications in the Northeastern U.S.

Eric H. Wharton
Douglas M. Griffith

Abstract

Existing literature on procedures for estimating tree biomass for northeastern tree species includes a number of research studies that are specific and localized. As a result, there is little consistency in these estimation procedures, which are largely in the form of regression equations. In additon, many species are ignored that need to be quantified when inventories of forest resources are conducted over extensive areas. This makes it difficult to determine the most appropriate biomass-estimation procedures. In this paper, an evaluation is made of prediction models and their application over the entire range of northeastern tree species. Recommendations are also made on procedures for the more nontimber oriented elements of total forest biomass--shrub biomass, foliage biomass, stump and root biomass, and biomass on unproductive forest land.

The Authors

ERIC H. WHARTON and DOUGLAS M. GRIFFITH are Foresters with the Forest Inventory and Analysis Unit at the Northeastern Forest Experiment Station, Radnor, Pennsylvania.

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U.S. Department of Agriculture, Forest Service
Northeastern Forest Experiment Station
5 Radnor Corporate Center, Suite 200
100 Matsonford Road, Radnor, PA 19087-4585

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Background

Since 1928, the USDA Forest Service has measured the Nation's forest resources, supplying information about their nature and condition. In the past, forest inventories focused on volume estimation: cubic feet for growing stock and board feet for sawtimber (these and other terms are defined in Appendix F). Volume statistics have proven useful to resource planners and managers for quantifying the timber supply and for tracking changes in the timber resource over time. But conventional methods for measuring timber volume do not adequately define conditions of the entire forest and, therefore, have limited applicability to the kinds of assessments required of today's resource planners, managers, and researchers.

We now recognize that our forests are not only a source of wood for traditional timber products but also of wood fiber for new industrial products and nonindustrial products such as fuelwood. In addition, the nation's forest resource plays an important part with respect to wildlife habitat, plant diversity, nutrient recycling, and biochemical interchanges so essential to our survival that are affected by climatic change and manmade pollution.

Over the years, the complete-tree concept has become more accepted even though methods for measuring the content of the whole tree have not always kept pace. Many methods for measuring biomass have been explored during the past couple of decades, but there is little consistency among them. The relationships that have been developed between common tree measurements and the weight of individual tree components, determined largely by regression equations, include many data-gathering and analytical techniques. The resulting concern over their applicability is compounded by the fact that many of the regression equations now being used are designed only for common species. The question then arises: which equations should be used for species for which a specific regression equation is not available?

Since It appears likely that research on environmental interactions, sometimes on a global scale, will not only continue but increase in complexity, and because social and economic factors and their interaction have increased pressure on our forest resources, it is necessary to evaluate the accumulated procedures for estimating biomass so that "complete-forest" assessments of the resource can be made. Keays (1971a, b, c, d, e) published the earliest synthesis of literature available on biomass estimation. Additional reviews of the North American literature were made by Young (1976) and Hitchcock and McDonnell (1979). Pelz (1987) reviewed European literature, and there have been regional reviews for the southern (Baldwin 1987) and northeastern (Tritton and Hornbeck 1982) United States. We are interested in these syntheses of the literature as they relate to the analysis and application of biomass regression techniques, particularly in the Northeastern United States.

An evaluation of available biomass-estimation techniques and their potential use as a base for regional biomass analyses of important tree species seems appropriate. The first factor to be considered is which unit of measure should be used–green weight or dry weight?

Biomass Units of Measure

Many factors contribute to variation of weight in trees; certainly moisture content is a critical one. In the past, green weight was commonly used by the USDA Forest Service to measure biomass supplies, at least in the Northeast, simply because green weight most closely approximates the condition of standing trees. And because it reflects the economic cost of removing wood from the forest, this measure is preferred by the timber-using industry. To the industry, however, merchantable-stem biomass may be the only green-weight statistic of value. Comparisons to dry weight can be made if needed, and yields of industrial forest products harvested and resulting residual weights can be developed from them.

By contrast, dry weight is more consistent over time, avoiding seasonal variations that occur when trees are measured in terms of green weight. The dry-weight measure also provides a more common base, yielding an easier solution to environmental questions such as those related to the carbon content of forests. Scientists prefer dry weight when accessing different biomass components because it allows analysis between trees and other vegetation.

Merchantable-stem biomass is best reported in both green weight and dry weight. Most of the other components of forest biomass–branches, foliage, stumps and roots, cull trees, seedlings and saplings, shrubs, etc.–are best reported in dry weight since biomass studies today tend to be directed more to vegetation analysis and biodiversity studies, that generally require biomass to be reported in dry weight.

Procedures for Estimating Green Weight

There are many regression equations that predict the green weight of trees and their components. We are interested in how well these equations predict the green weight of trees in areas for which equations have not been developed. Tritton and Hornbeck (1982) indicated that while most biomass equations for northeastern tree species have been developed locally and their use has been relatively limited, some may be useful for predicting weights of trees over extensive geographic regions. But Hocker and Early (1983) argued against using equations to predict weights of trees over large regions. A study by Jacobs and Monteith (1981) has shown that the weights of identical northeastern tree species are similar in different regions of the Northeast. And results from a more indepth study (Barrett and Jastrembski 1990) based on an analysis of indicator variables showed that differences in tree green weight between locations may not be important enough to preclude using regional models on a wide geographic scale. Sufficient research has been conducted to assure us of the validity of using regional biomass equations.

Regional Regression Equations

We used regional regression equations developed by Barrett and Jastremski (1990) from sources in New Hampshire, New York, Ohio, West Virginia, and Michigan.

The form of the regional regression equation is:

$$Y = b_0 + b_1(D^2H)$$

where the dependent variable Y is total tree-stem biomass (in green pounds), and the independent variables D and H are, respectively, diameter at breast height (in inches) and total tree height (in feet). Regression coefficients for 14 species were developed (Table 1). Species with no specific regression coefficients were grouped with those that did based on similar green-weight densities (Appendix A). Species for which there is a regression equation are called "key species" in this report.

The Forest Inventory and Analysis research unit of the USDA Forest Service equates the merchantable stem to growing stock, that is, the tree bole between a 1.0-foot stump height and a specified top. The growing-stock top is at a minimum 4.0-inch diameter outside the bark on the central stem, or the point at which the central stem breaks into branches if this occurs before the minimum diameter is reached.

Table 1. Total stem-weight regression coefficients for selected species

$$Y = b_0 + b_1(D^2H)$$

Y = green weight (in pounds)
D = diameter at breast height (in inches)
H = total tree height (in feet)

Species	Coefficients b_0	Coefficients b_1
Hemlock	45.05	0.1856
Spruce	235.95	0.1378
Pine	116.92	0.1547
Fir	113.77	0.1603
Oak	51.28	0.1797
Maple	56.09	0.1663
Hickory	-58.58	0.2046
Basswood	19.95	0.1344
Aspen	53.47	0.1549
Cherry	-19.37	0.1753
Birch	-47.78	0.2076
Yellow-poplar	-39.77	0.1439
Ash	16.81	0.1496
Beech	34.69	0.2245

Since the regional model predicts total-stem biomass, adjustments had to be made to quantify merchantable-stem biomass (growing-stock biomass). First, conversions were applied that relate total-stem biomass (the parameter predicted by the regional model) to aboveground tree biomass on a green-weight basis from regression equations developed by Monteith (1979). Then, conversions from the same study were applied that relate aboveground tree biomass to merchantable-stem biomass (the parameter of interest). The relationship of total-stem and merchantable-stem to aboveground tree biomass were averaged by evergreen and deciduous species, and by standard Forest Service stand-size classes (Table 2).

In the regional model, total tree height is used as an independent variable to predict biomass. This is a limitation because trees often are measured only to a certain merchantable height, as is done by Forest Inventory and Analysis. The regional equations described are unusable unless total tree height can be measured or predicted.

Total Tree Height

Measuring the total height of sample trees has been considered frequently in statewide inventory designs. Given the high cost of obtaining tree information as currently collected, we have found the cost of measuring total tree height to be prohibitive. Yet the value of total tree height cannot be overstated, especially considering its use as a parameter in many biomass regression equations. Most equations that predict total tree biomass incorporate total tree height. And in some instances, it can prove to be a significant predictor of biomass. Because of great differences in height over the range of some species, the measure of total tree height often is seen as essential.

Cunia and others (1984) developed a procedure for predicting total tree height from diameter and merchantable-height measurements on forest inventory field plots. Developed to simulate populations of trees in order to test sample designs, this procedure can be applied to actual tree dimensions.

The form of the model is:

$$Y = b_0 + b_1(D) + b_2(H)$$

where the dependent variable Y is total tree height (in feet); the independent variables D and H are, respectively, diameter at breast height (in inches) and merchantable height (in feet). Consequently, we did not have to measure total tree height but could estimate it from measurements we already had.

Regression coefficients for 17 species were used (Table 3). Species with no specific regression coefficients were grouped with those that did based on average height and bole and crown characteristics that most closely approximated a species for which there was an equation (Appendix D).

Generally, evergreen species of similar heights were grouped together. These groupings occurred mostly within the same genus, e.g., red pine was used for pines. Deciduous species were more difficult to group because of their many different bole and crown characteristics.

Table 2. Total-stem biomass and merchantable-stem biomass as a percentage of aboveground tree biomass, green-weight basis

Stand-size class	Total stem		Merchantable stem	
	Evergreen	Deciduous	Evergreen	Deciduous
Poletimber	0.7617	0.8010	0.6503	0.7269
Small sawtimber	0.8032	0.7990	0.7695	0.7737
Large sawtimber < 21.0" d.b.h.	0.8194	0.7979	0.8053	0.7852
Large sawtimber ≥ 21.0" d.b.h.	0.8235	0.7975	0.8136	0.7884

Table 3. Total tree-height regression coefficients for selected species

$$Y = b_0 + b_1 (D) + b_2 (H)$$

Y = total tree height (in feet)
D = diameter at breast height (in inches)
H = merchantable height (in feet)

Species	Coefficients		
	b_0	b_1	b_2
Red maple	21.425	0.0000	1.03546
Sugar maple	33.477	0.0000	0.85822
Yellow birch	46.935	0.0000	0.48425
Beech	24.479	0.0000	0.93307
White ash	30.779	0.0000	0.87421
Black cherry	31.520	0.0000	0.78366
Basswood	39.430	0.0000	0.66960
Yellow-poplar	39.572	0.0000	0.63497
White oak	33.639	1.5880	0.29821
Scarlet oak	40.751	0.0000	0.53881
Chestnut oak	41.585	0.0000	0.48834
Northern red oak	40.805	0.0000	0.62504
Black oak	29.915	0.0000	0.79821
Trembling aspen	9.760	0.0000	1.11161
Balsam fir	19.818	0.0000	0.76839
Red pine	17.977	0.0000	0.85621
White spruce	11.924	0.0000	0.93523

Among deciduous trees with well-formed boles and open, irregular crowns, white ash, sugar maple, and yellow birch were designated as key species. Yellow birch was used for small trees, sugar maple for medium trees, and white ash for tall trees exhibiting these growth characteristics. Among deciduous trees with straight, clear boles and small, oblong or narrow crowns, yellow-poplar, basswood, and black cherry were designated as key species. Black cherry was used for small trees, basswood for medium trees, and yellow-poplar for tall trees with these characteristics.

As a group, oaks exhibit many bole and crown characteristics, but white oak and chestnut oak tend to have shorter boles and wide, spreading crowns. So chestnut oak was used for smaller oaks and white oak was used for taller oaks with these characteristics. Similarly, black oak and northern red oak were used for smaller and larger oak trees, respectively, but for trees with straight boles and relatively smaller crowns. Finally, scarlet oak was used for oaks with relatively straight boles but more irregularly shaped crowns.

Two species remained for which we had found equations–beech and red maple. Beech was used for deciduous trees with large tree boles and large, spreading crowns. Red maple was used for small deciduous trees with irregular crowns–the majority of the trees found in the Northeast.

This technique of grouping species with those that have regression equations for predicting total tree height based on observable growth characteristics should be used only if no other means are available. Other possibilities are to develop similar groupings based on local average tree heights, height and diameter relationships, periodic and mean annual height-growth curves, and cross-sectional stem analysis. We assumed that simple growth characteristics are sufficient to place species into appropriate groupings for predicting total tree height.

Procedures for Estimating Dry Weight

For extensive forest surveys, the most important parts of total forest biomass to report (Fig. 1) are:

•The woody biomass in the merchantable stem of growing-stock trees (also called growing stock), which can be further apportioned into poletimber, sawtimber, and the upper stem portion above sawtimber.

•Additional sources of biomass in growing-stock trees–branches, foliage, and the stump-root system–and cull trees which together constitute timber.

•The biomass in nontimber trees, e.g., salvable dead trees, seedlings, and saplings.

•Other kinds of nontree-related forest biomass, for example, shrubs.

•The biomass on land that is not capable of producing commercial crops of timber.

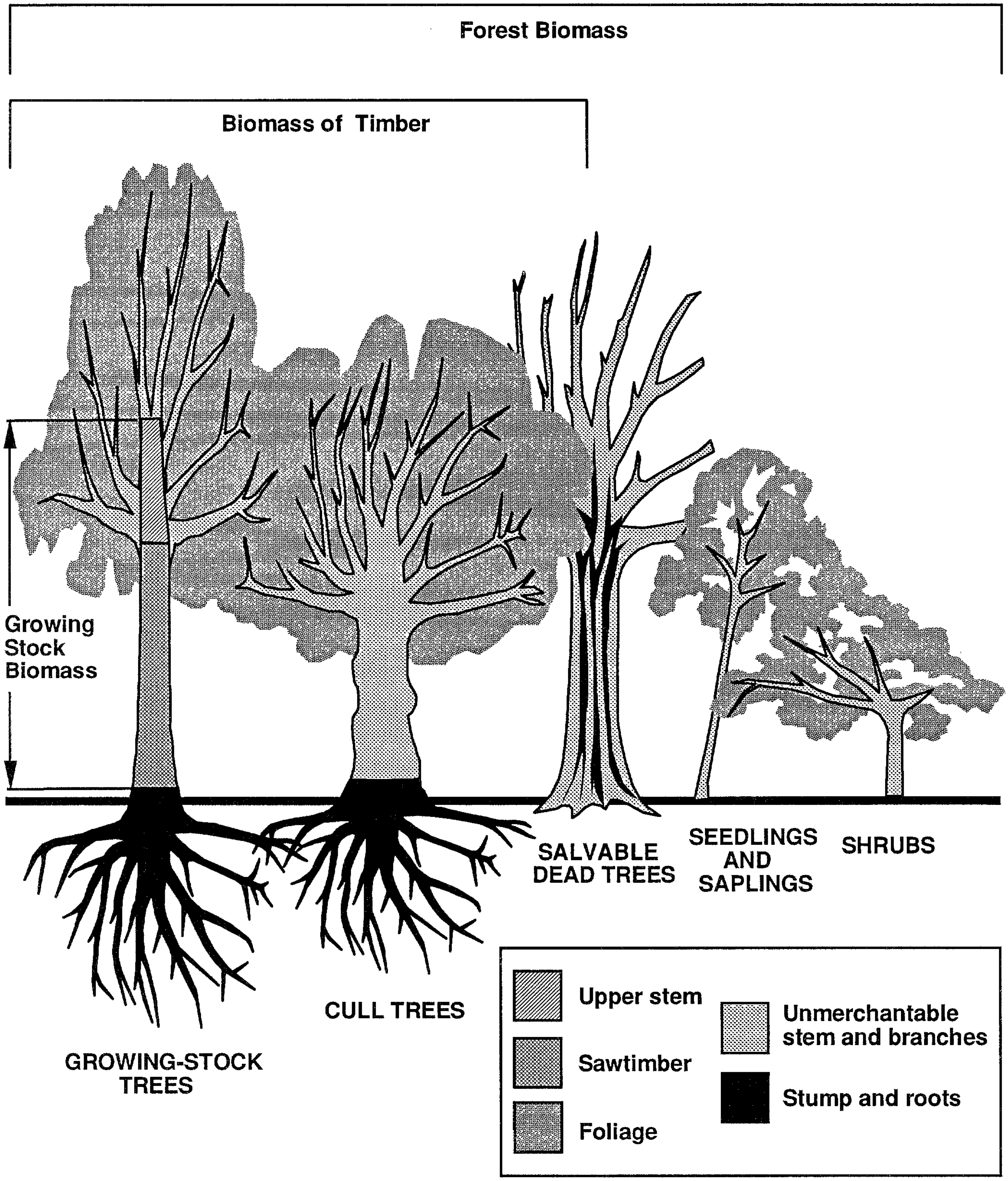

Figure 1. Relationship of total forest biomass components

Biomass of Growing Stock

Growing-stock trees are live, predominantly sound trees from which it is possible to harvest commercial timber products. When measuring the volume of growing-stock trees, it is customary to deduct the volume of rotten cull when reporting board-foot volume, and to also deduct the volume of sound cull (grade deductions that are still solid wood) when reporting cubic-foot volume. Rotten cull affects tree weight, but sound cull does not, so only the percentage of rotten cull in a tree is deducted when reporting tree quantities in terms of weight.

Three sets of regression equations were chosen from the literature that covered the greatest range of species encountered in the Northeast: Young and others (1980) developed models for species in Maine, Wiant and others (1977) developed models for species in West Virginia, and Monteith (1979) developed models for species in New York.

Equations developed in Maine were the source for all evergreen species found: balsam fir, eastern white pine, red pine, spruce, hemlock, northern white-cedar, and larch; and for some deciduous species: red maple, yellow birch, and aspen. Equations developed in West Virginia were the source primarily for Appalachian deciduous species: hickory, yellow-poplar, black cherry, white oak, scarlet oak, chestnut oak, northern red oak, and black oak. Equations developed in New York were the source for sugar maple, American beech, and white ash.

The form of the models to predict aboveground woody biomass for those developed in Maine (1), West Virginia (2), and New York (3) are:

$$\mathrm{Ln}Y = b_0 + b_1\mathrm{Ln}(D) \qquad (1)$$

$$\mathrm{LOG}_{10}Y = \mathrm{LOG}_{10}b_0 + b_1\mathrm{LOG}_{10}(D) \qquad (2)$$

where Ln is the natural logarithm, the dependent variable Y is dry weight (in pounds), and the independent variable D is diameter at breast height (in inches); and

$$Y = b_0 + b_1(D) + b_2(H) + b_3(D^2H) \qquad (3)$$

where the dependent variable Y is dry weight (in kilograms), and the independent variables D and H are, respectively, diameter at breast height (in millimeters) and merchantable tree height (in meters). Regression coefficients for 21 species were developed (Table 4). Species with no specific regression coefficients were grouped with species that did based on similar dry-weight densities (Appendix B).

Biomass of Timber

The biomass of growing stock can be extended to include portions of the entire growing-stock tree–branches, foliage, stumps, and roots. Also included were cull trees, which along with the biomass of individual components of growing-stock trees comprise the biomass of timber.

Table 4. Aboveground tree-weight regression coefficients for selected species

$$\mathrm{Ln}Y = b_0 + b_1\mathrm{Ln}(D) \qquad (1)$$

$$\mathrm{LOG}_{10}Y = \mathrm{LOG}_{10}b_0 + b_1\mathrm{LOG}_{10}(D) \qquad (2)$$

$$Y = b_0 + b_1(D) + b_2(H) + b_3(D^2H) \qquad (3)$$

Y = dry weight (in pounds or kilograms)
D = d.b.h. (in inches or millimeters)
H = merchantable height (in meters)

Species	Coefficients			Equation number
	b_0	b_1	b_2	
Balsam fir	0.5958	2.4017	—	1
Eastern white pine	0.4080	2.4490	—	1
Red pine	0.7157	2.3865	—	1
Spruce	0.8079	2.3316	—	1
Hemlock	0.6803	2.3617	—	1
N. white-cedar	1.1182	1.9269	—	1
Larch	0.8162	2.2453	—	1
Red maple	0.9392	2.3804	—	1
Sugar maple	5.2480	0.3661	0.0076	3
Yellow birch	1.1297	2.3376	—	1
Hickory	1.9338	2.6209	—	2
American beech	5.3373	-0.3257	0.0072	3
White ash	3.2031	-0.2337	0.0061	3
Yellow-poplar	1.5779	2.5153	—	2
Black cherry	2.5883	2.4253	—	2
Aspen	0.4689	2.6087	—	1
White oak	1.2892	2.7010	—	2
Scarlet oak	2.6574	2.4395	—	2
Chestnut oak	2.1202	2.5344	—	2
Northern red oak	1.6891	2.6598	—	2
Black gum	2.1457	2.5050	—	2

Bark also could be included but little research has been conducted on the amount of bark biomass contained in standing trees, either on a green- or dry-weight basis. For those interested in estimates of bark biomass, one technique is to divide estimates of whole-tree wood biomass by estimates of whole-tree wood and bark biomass. Comparative regression equations useful for this purpose have been synthesized from the literature and presented in tabular format by the USDA Forest Service (1984). However, they were developed mostly for southeastern tree species.

Branch biomass–We derived biomass in branches from regression equations developed by Young (1980). By dividing the weight of branches by total aboveground tree biomass, the proportion of branch biomass can be determined using averages by evergreen and deciduous species and by stand-size class (Table 5). Resulting branch percentages are applied to estimates of aboveground biomass provided by the dry-weight procedures outlined.

Foliage biomass–This component of forest biomass has taken on more importance recently. It has been used as a data input for determining hydrocarbon emissions and is a critical component of research on carbon sinks and sequestering. Foliage biomass can be estimated through the same technique as outlined for branches. Average proportions are presented in Table 5.

Stump/root biomass–Information on stumps and roots seems of little value currently, but it may be of more value in the future. This component can be estimated by the same technique as described for branches. Average proportions are presented in Table 5.

Cull trees–These are trees with more than 67 percent of their volume deducted due to rot or poor form. As with other timber trees, only rotten cull is deducted to determine net weight. Cull trees pose no special problem other than that the regression equations may not fit trees of poor form. Some of these trees may be wolf trees whose biomass could be underestimated because regression equations usually are developed for dominant and codominant trees. Until regression equations are developed for rough, poorly formed, and similar kinds of trees, the biomass equations now available will have to suffice.

Forest Biomass

When other kinds of nontimber such as salvable dead trees, small trees, and shrubs are added to the biomass of timber, we approach total forest biomass. Biomass on unproductive forest land also is a necessary component if researchers are to have a complete picture of the total biomass on our forests. Even grasses, forbs, and other types of nontimber vegetation have been measured in parts of the country (Mead and others 1987; Yarie and Mead 1988, 1989), other than the Northeast.

Salvable dead trees–These are dead trees with intact bark. Excluded from this particular classification of nontimber are snags, which have lost their bark and for the most part contain no sound wood. Salvable dead trees are assumed to contain sound wood, and are treated in the same way as cull trees.

Table 5. Branch biomass and foliage biomass as a percentage of aboveground tree biomass, and stump-root biomass as a percent of complete tree biomass, dry-weight basis

Stand-size class	Branches		Foliage		Stump/root	
	Evergreen	Deciduous	Evergreen	Deciduous	Evergreen	Deciduous
Poletimber	0.1126	0.0348	0.1402	0.1093	0.2033	0.2109
Small sawtimber	0.0960	0.0268	0.1410	0.0991	0.2030	0.2013
Large sawtimber < 21.0" d.b.h.	0.0860	0.0224	0.1427	0.0932	0.2032	0.1943
Large sawtimber ≥ 21.0" d.b.h.	0.0768	0.0175	0.1457	0.0860	0.2040	0.1844

Seedlings and saplings–Seedlings are trees less than 1.0 inch d.b.h., and saplings are trees at least 1.0 inch d.b.h. but less than 5.0 inches d.b.h. A single regression equation may be sufficient to estimate their aboveground biomass.

In a study by Tritton and Hornbeck (1982), graphical analysis of biomass regression equations for a single species–red maple–showed little differences in the smaller diameter classes. The regressed lines diverged between a d.b.h. of 15 and 20 cm (6 and 8 inches). For trees between 1 and 5 inches d.b.h., the regression equations were virtually identical. Additional graphical analysis that we conducted showed that regression equations for many different species did not appear to differ for small-diameter trees.

A single biomass regression equation chosen from the literature to predict the weight of small trees should be selected on the basis of the following criteria:

- D.b.h. must be the sole independent variable used to predict tree weight since total tree height usually is not measured for saplings. Because saplings have no merchantable height, the regression equation to predict total tree height from diameter and merchantable height cannot be used.

- Aboveground tree weight must be predicted on a dry-weight basis.

- Tree weight must be predicted for as many of the most common northeastern species as possible.

A biomass regression equation developed by Wartluft (1977) met all of these criteria. In his study conducted in West Virginia, 17 randomly selected, naturally occurring Appalachian deciduous species (Table 6) were weighed and a single biomass equation developed using d.b.h. as the sole predictor of aboveground tree biomass.

Equations to predict both green and dry weight were developed. The dry-weight equation is:

$$\mathrm{Ln}Y = 1.54934 + 2.39376\ \mathrm{Ln}\ (D)$$

where Ln is the natural logarithm, the dependent variable Y is total aboveground tree biomass (in dry pounds), and the independent variable D is d.b.h. (in inches).

Table 6. Species and number of observations used to develop a biomass regression equation for small Appalachian deciduous species

Species		n
Common name	Scientific name	
Soft maple	*Acer rubrum*	47
Hard maple	*A. saccharum*	9
Sweet birch	*Betula lenta*	1
Hickory	*Carya sp.*	13
Dogwood	*Cornus florida*	2
Beech	*Fagus grandifolia*	2
Yellow-poplar	*Liriodendron tulipifera*	4
Cucumber	*Magnolia acuminata*	2
Mountain magnolia	*M. fraseri*	3
Blackgum	*Nyssa sylvatica*	4
Sourwood	*Oxydendrum arboreum*	12
Aspen	*Populus sp.*	2
Black cherry	*Prunus serotina*	1
White oak	*Quercus alba*	28
Chestnut oak	*Q. prinus*	32
Red oak	*Q. sp.*	31
Sassafras	*Sassafras albidum*	7

Shrubs-interest in shrub biomass has continued to increase because of biodiversity studies and research on global climate change, carbon sequestering, wildlife habitats, and forest fuel. A recent national biomass report (Cost and others 1990) included this component of forest biomass that is not usually assessed. At that time, shrub biomass statistics were available only for the North-Central United States and Alaska.

As with the biomass of timber, shrub biomass can be determined by regression equations extracted from the literature. Most equations that predict shrub biomass include some measure of diameter, either at the base or at some point above that. Unfortunately, diameter measurements are not taken for the shrubs encountered on our field plots, only stem counts. As a result, median stem diameters had to be substituted for diameters in the shrub biomass equations. These were obtained from the source of the equations themselves.

Since the North Central Forest Experiment Station has led in the development of shrub-biomass statistics, the shrub-biomass equations were obtained from Smith and Brand (1983). They synthesized equations from various sources along with ranges of diameters which could be used to determine average stem diameter. Occasionally, several equations were available for a particular species, so decisions had to be made concerning the best equation to use.

The first selection criterion is that equations must predict both total aboveground biomass and foliage biomass. Those that did not predict foliage biomass or predicted only woody aboveground biomass were excluded. The second criterion is geographic source–equations that were developed closest to the Northeast were selected over those developed elsewhere. Finally, equations that had higher correlation coefficients (r^2) were selected. These three criteria were sufficient to judge the equations suitable for each species and resulted in regression equations for 30 species (Table 7).

The form of the equation is:

$$Y = b_0(D)^{b_1}$$

where the dependent variable Y is total aboveground biomass (in oven-dry grams), and the independent variable D is the median stem diameter (in centimeters).

In the shrub-biomass equations, two diameter measurements were used. Most included basal stem diameter, but some included diameter 15 cm aboveground. This did not influence the results because median stem diameters (based on the range of published diameters) are used to determine average biomass per stem, which are then applied to stem counts.

An equation for a single vine species–vine honeysuckle (*Lonicera hirsuta*) also was found. At this time, vines (and dwarf shrubs) are excluded from assessments of shrub biomass. However, vines may be included in future assessments. In anticipation of this, the coefficients for vine honeysuckle are included in Table 7.

Unproductive forest land–By USDA Forest Service definition, unproductive forest land is forest land from which no commercial crops of timber can be harvested. This definition is biased toward timber harvesting but in no way reflects on the capability of such an area to provide other goods and services. Biomass from this land class is a necessary component of the biological potential of an area and should be included in any resource assessment of the total forest resource.

However, because of the very nature of the resource surveys conducted by the Forest Service, it is difficult to quantify biomass on forest land other than timberland. The forest surveys are designed primarily to measure the volume of growing timber, so few plots fall on unproductive forest land, urban forest land, or reserved forest land. However, area estimates of reserved forest land are available from public agencies. The simplest way to quantify biomass on reserved forest land, and the one we have adopted, is to obtain average biomass per acre on timberland, and apply those ratios to known land areas classified as reserved. Since reliable information is not available for unproductive land or urban land, we must rely on the data provided by the plots encountered (even though sampling errors will be high).

Species Groups

Most biomass regression equations are for a limited number of species. Species for which no regression equation is available must be grouped with other, related species for which an equation is available.

In the past, density and tree form were the primary criterion for segregating tree species. Brenneman and others (1978) used excurrent and deliquescent determinations as a measure of tree form. Excurrent branching is descriptive of a tree whose main axis or trunk extends to the top of the crown, for example, pine, spruce, and fir; deliquescent branching is descriptive of a tree lacking a main axis–elm is an extreme example (Harlow and Harrar 1969).

These classifications add little to distinguish branching habit over much simpler classifications such as evergreen and deciduous species. Most evergreens are excurrent and most deciduous species are delequiscent. A more detailed method for grouping species is required.

Table 7. Shrub-biomass regression coefficients for selected species

$$Y = b_0(D)^{b_1}$$

Y = dry weight (in grams)
D = median stem diameter (in centimeters)

Species[a]	Aboveground biomass coefficients		Foliage biomass coefficients		Median stem diameter (cm)	Source[b]
	b_0	b_1	b_0	b_1		
Alnus sp.	63.280	2.380	14.725	1.828	2.45	Minnesota (b)
Berberis repens	19.609	2.092	8.174	1.586	0.60	Idaho/Montana
Ceanothus velutinus	39.252	2.847	14.688	2.415	1.55	Idaho/Montana
Chamaedaphne calyculata	41.330	2.626	10.566	2.220	0.48	Canada
Comptonia peregrina	44.691	3.314	13.585	3.014	0.84	Canada
Cornus rugosa	74.114	2.457	17.131	2.093	1.95	Minnesota (b)
C. stolonifera	32.791	3.806	7.992	2.440	1.00	Minnesota (a)
Corylus cornuta	62.819	2.420	12.115	2.010	1.40	Minnesota (b)
Gaylussacia baccata	44.942	2.156	13.950	1.502	1.52	Canada
Hamamelis virginiana	38.111	2.900	9.480	2.162	2.24	Canada
Ilex verticillata	53.497	3.340	10.747	2.851	0.54	Canada
Juniperus communis	59.205	2.202	30.387	1.650	1.85	Idaho/Montana
Kalmia augustifolia	26.692	2.384	8.497	2.091	0.48	Canada
Ledum groenlandicum	37.597	2.832	12.331	2.413	0.53	Canada
Lonicera canadensis	51.996	2.770	15.610	2.399	0.40	Canada
L. hirsuta[c]	46.002	3.402	3.926	1.163	0.38	Minnesota (c)
Menziesia ferruginea	21.607	3.150	1.937	2.263	1.25	Idaho/Montana
Myrica pensylvanica	60.795	2.867	18.361	2.529	0.70	Canada
Nemopanthus mucronatus	31.532	2.819	4.246	2.231	1.50	Canada
Physocarpus malvaceus	41.679	2.576	9.728	2.036	2.10	Idaho/Montana
Rhamnus alnifolia[d]	30.791	2.764	2.009	3.835	1.12	Minnesota (c)
Rhododendron canadense	24.079	2.612	5.183	2.050	0.68	Canada
Ribes sp.	49.001	3.112	8.706	2.538	0.90	Idaho/Montana
Rosa sp.	37.637	2.779	7.561	2.112	0.70	Idaho/Montana
Rhubus idaeus	43.992	2.860	18.394	2.932	0.60	Idaho/Montana
Shepherdia candensie	33.016	2.407	7.463	2.034	1.80	Idaho/Montana
Spirea sp.	36.648	2.579	5.493	1.720	0.68	Canada
Symphoricarpos alba	32.786	2.285	6.437	1.721	0.70	Idaho/Montana
Vaccinium sp.	95.143	3.706	13.224	3.034	0.35	Canada
Viburnum latinoides	43.570	2.774	7.143	2.205	1.70	Canada

[a]Species presented are common shrub species of the North-Central United States. Scientific names are given to relate these species to shrub species found in the Northeastern United States.

[b]Sources are: Canada, Maritime Provinces (Telfer 1969); Idaho/Montana, northern Idaho and western Montana (Brown 1976); Minnesota (a), northern Minnesota (Connally 1981); Minnesota (b), northern Minnesota (Roussopoulos and Loomis 1979); and Minnesota (c), northeastern Minnesota (Grigal and Ohmann 1977).

[c]Vine honeysuckle, a vine species currently excluded from the assessment.

[d]Woody aboveground biomass is used as the dependent variable in the equation to predict aboveground biomass because an equation for total aboveground biomass is unavailable.

Smith (1962) recognized a natural tendency of tree species to regulate branchiness depending on the degree of light tolerance. Relatively intolerant species are most likely to lose their lower branches through natural pruning. Species such as Douglas fir, yellow-poplar, and ash are examples. Shade-tolerant species such as hemlock, fir, and beech, frequently are branchy. A measurable tree parameter relating to branching habit, such as crown ratio, could be used. Crown ratio relates to the percentage of total tree height that supports a full, live crown, and can be used as an indicator of light tolerance.

Assessments relating tree species to crown ratio have not been made to date, but should be considered for the future. In the meantime, density alone will have to suffice when grouping the species to which the tree-biomass regression equations will be applied. Tables of density with associated species groupings on a green- and dry-weight basis (Appendix A and B) have been developed entirely from the literature. The primary source of information was Markwardt (1930), who published densities on both green and dry basis, and specific gravities for 75 northeastern tree species. Additional dry-weight densities were from Peattie (1958).

Species were segregated into evergreen and deciduous species. All tree species for which there is no biomass regression equation were matched with the closest species that did on the basis of both green and dry weight. Shrub species with no specific regression coefficients were grouped with those that did based on similar form (Appendix C).

Judgments were made as to which density should be used when equations were unavailable for a particular species. These judgments were related to the morphology, taxonomy, and utilization characteristics of the species in question, and were based on information in Harlow and Harrar (1969), Johnson (1973), Peattie (1958), and Shaw (1914). If a judgment could not be made on the basis of these criteria, averages were assigned. Averages were developed for evergreen, light deciduous, and heavy deciduous species. The distinction between light and heavy deciduous species has been commonly accepted to be a specific gravity of 0.50.

Species greater than or equal to 0.50 were considered heavy deciduous, and those less than 0.50 were considered light deciduous species. This classification has been checked for consistency with species segregated into soft and hard deciduous species by the Forest Service. There is a difference only for winged elm. The Forest Service considers this species a soft deciduous species, but we have treated it similar to rock elm, that is, a heavy deciduous species.

The densities we used were oven dry, based on volume when green (Markwardt 1930). Species densities were averaged over 226 evergreen trees, 251 light deciduous trees and 425,424 heavy deciduous trees that Markwardt reportedly tested. The tables of species density in this report are footnoted to clarify where judgments were made.

Application to Extensive Surveys

The Forest Service conducts periodic forest inventories of all states in the Nation. Authority to conduct these inventories is provided by the McSweeny-McNary Forest Research Act of 1928 and subsequent acts, including the Renewable Resources Planning Act of 1974 and the Renewable Resources Research Act of 1978.

The Forest Inventory and Analysis unit of the Northeastern Forest Experiment Station is responsible for conducting periodic forest inventories in 14 northeastern states. A recent inventory of Ohio provided an opportunity to show how procedures for estimating biomass can be applied to an extensive forest area. Ohio is one of the first Northeastern states for which biomass statistics were published (Dennis 1983). Since that time our estimation techniques have been refined. Data for the most recent inventory, the fourth of its kind for Ohio, were collected during 1990 and 1991 (Griffith and others 1992).

Methods and Specifications

The inventory design employs a multistage sampling procedure of aerial photo points and a subsample of ground plots. The basic design entails sampling with partial replacement, using previous inventory data. Remeasurement is based on selected ground plots from inventories conducted for 1952, 1968, and 1979. These inventories were based on sampling designs that featured a combination of photo and ground plot techniques. Field crews observed a large sample of 1-acre plots on aerial photographs, then permanently located a subsample of 1/5-acre and 10-point prism ground plots, tallying tree and area data on these plots.

The current sample is based on interpretation of points on new aerial photographs for stratification into land use and cubic-foot volume classes. A sample of these points stratified as forest land and nonforest land was selected for ground observation; a subsample of 4,807 ground plots was measured. Means and variances for each photo stratum were calculated from the ground sample. Of these ground plots, all were remeasured plots, though 38 new 10-point prism plots were installed on National Forest lands.

The current inventory of Ohio is designed to make efficient use of previous data while capitalizing on the additional stratification possible from the new photography. Since a sample of previous plots was remeasured, the sampling scheme is called Sampling with Partial Replacement. However, since the remeasurement portion was so great, no updating of unremeasured plots was undertaken.

The primary building blocks for reporting results are counties. One of the prerequisites for developing county-level statistics is that a county must have at least 60,000 acres of timberland. Counties that do not meet this criterion have too few plots to allow reliable estimates. Such counties are grouped with a neighboring county or counties to form a sampling base large enough to provide reliable estimates (Fig. 2). These are called supercounties. Cuyahoga County was excluded because all the forest land within that county was classified as urban, and therefore, not timberland.

It is to this sampling base that biomass-estimation procedures described have been applied. The tables that result provide a guide to the kinds of information required by data users. Judgments were based on a decade of supplying biomass-related information to forest-land managers, policymakers, and others operating within the forest community.

Structure of Biomass Tables

The tables that follow are divided into four broad groups. The first three relate volume, green weight, and dry weight within the merchantable-stem portion of growing-stock trees. The tables that follow these depict an increasingly broader range of biomass information–first, all timber, and then all forest biomass. The final table shows the broadest classification of biomass on total forest land. Some of the data in the final table is sketchy. The forest survey was designed to primarily determine timber production, so predominantly urban areas and areas in Christmas tree production were excluded.

Cuyahoga county was excluded from the survey because all forest land in the county was classified as urban, and therefore, not timberland. Since it was excluded from previous tables, for consistency, it was also excluded from the final table. However, the area and biomass are footnoted. Likewise, the area in Christmas tree production has been excluded. Christmas trees are assumed never to reach timber size, so no measurements were taken that would have enabled estimation of biomass. The area, however, has been footnoted.

Except for the first two tables, all tables report biomass on a dry-weight basis in English units. Conversions and metric equivalents have been provided for data users requiring green-weight biomass statistics, for calculating energy values, or for converting the data to metric units.

In most of the tables, biomass is reported by evergreen and deciduous species. Classical distinctions of softwoods and hardwoods seem inappropriate for some components. The biomass of shrubs is one example. More descriptive terms were required to identify species groups even though nearly every classification is somewhat misleading. For example, some evergreen species loose their needles annually, and some deciduous trees have persistent leaves. Evergreen/deciduous was preferred to both the softwood/hardwood or the coniferous/broad-leaved classifications.

It should be noted that cell estimates may not sum to row and column totals. Because of the way in which sample data has been expanded to develop the statistics, rounding errors will occur. Sometimes, an estimate of zero occurs in the cells. This may not mean that a true null quantity exists but that no sample trees may have been encountered for that cell. This also happens when trees may have been sampled but the resulting biomass was fewer than 500 tons; consequently, the total is rounded to zero when reported in millions of tons

Figure 2. Ohio counties and supercounties, by geographic unit

Reliability of the Estimates

The data in this report were based on a carefully designed sample of forest conditions throughout Ohio. But since field crews did not measure every tree or every acre in the state, the data are estimates. The reliability of the estimates can be judged by two important statistical measures: accuracy and precision. Accuracy refers to the success of estimating the true value; precision refers to the clustering of sample values about their own averages–the variation among repeated samples.

We are interested primarily in the accuracy of the inventory, but in most cases we can only measure precision. However, accuracy can be increased by keeping sources of procedural error to a minimum through careful training of personnel, frequent inspection of work, and application of the most reliable inventory methods.

The precision of an estimate is described by sampling error. In this report, It is expressed as a percentage of the estimate corresponding to one standard deviation, calculated as the square root of the variance, divided by the estimate, and multiplied by 100.

The sampling errors reported are for row and column totals only. However, Alegria and Scott (1991) have developed a procedure to approximate individual cell sampling errors from row and column totals. An indication of the magnitude of the cell sampling errors is provided. Estimates that have associated sampling errors greater than 25 percent but less than 50 percent are denoted by (†). These estimates are suspect and should be used with caution. Cell estimates that have associated sampling errors greater than or equal to 50 percent are denoted by (‡). These cell estimates are not significantly different from zero, and are unreliable.

The sampling errors are used as follows: the estimate of total biomass of timber on Ohio timberlands is 459.3 million dry tons. The estimate has an associated sampling error of 1.8 percent, or 8.3 million dry tons. This means that if the inventory were repeated, the odds are 2 to 1 (66 percent probability) that the resulting estimate would be between 451.0 and 467.6 million dry tons. The odds are 19 to 1 (95 percent probability) that the resulting estimate would be between 442.7 and 475.9 million dry tons.

State estimates have the smallest sampling errors and, therefore, are the most precise. County estimates are less reliable. For example, the sampling error for total biomass of timber on Ohio timberlands is 1.8 percent. The similar estimate for Adams County is 8.7 percent. In general, as the size of the estimate decreases in relation to the total, the sampling error increases.

To improve the reliability of the estimates, cell values can be combined to reduce the sampling error. Data users may require combinations of counties, components, etc. that are different from those we might select.

As a general rule, the sampling error of a combined estimate will be approximately equal to or less than the smallest sampling error of the two estimates that are being combined. However, because individual cell values that have resulted from the inventory are independent, the calculated sampling errors of combined cells will be approximations. They will underestimate the true sampling error, but will be sufficient to make judgments of acceptability.

Combining cell values will not always reduce sampling errors to acceptable levels, so sampling errors of combined estimates must be calculated to determine if the sampling errors have indeed been reduced to acceptable levels. The technique to approximate the sampling error of a combined estimate is not difficult and entails using the following formulas:

$$v(X_t) = (s_1 X_1)^2 + (s_2 X_2)^2$$

$$s(X_t) = \frac{v(X_t)}{X_t}$$

where;

X_1 = first cell-value estimate

X_2 = second cell-value estimate

X_t = combined cell-value estimate

s_1 = sampling error of first cell value estimate

s_2 = sampling error of second cell value estimate

$v(X_t)$ = variance of combined cell value estimate

$s(X_t)$ = sampling error of combined cell value estimate

Index to Ohio Biomass Tables

Conversions and Metric Equivalents

1 cubic foot of softwoods = 0.027 green tons
1 cubic foot of hardwoods = 0.033 green tons
1 green ton of softwoods = 9.0 million b.t.u.
1 green ton of hardwoods = 8.6 million b.t.u.
1 green ton = 2.1 dry tons

1 inch = 2.54 centimeters
1 cubic foot = 0.02832 cubic meters
1 ton = 2,000 pounds
1 ton = 907.1848 kilograms
1 acre = 0.4047 hectares

Volume of growing stock on timberland, by county and component, Ohio, 1991

County and geographic unit	Poletimber	Sawtimber: Sawlog	Sawtimber: Upper stem	Total growing stock	Sampling error
	thousand cubic feet				*percent*
Adams	92,806	38,355	170,098	301,259	8.4
Brown	39,343	18,369	86,196	143,908	17.6
Clermont	46,093	14,056	61,270	121,418	16.3
Gallia	91,614	18,853	81,579	192,046	9.8
Highland	35,663	14,712	67,012	117,387	17.3
Jackson	64,553	20,462	96,240	181,255	10.3
Lawrence	88,900	40,996	184,911	314,807	10.5
Pike	56,257	25,745	114,323	196,325	10.4
Ross	54,973	27,029	123,971	205,973	12.0
Scioto	104,793	56,432	253,132	414,356	9.9
TOTAL, SOUTH CENTRAL UNIT	674,994	275,009	1,238,731	2,188,734	3.7
Athens	81,641	36,433	160,970	279,044	8.8
Hocking/Perry	158,138	55,293	258,033	471,464	7.5
Meigs	75,952	28,964	122,761	227,677	9.5
Morgan/Washington	167,479	63,302	298,011	528,792	8.5
Vinton	97,824	40,406	180,556	318,787	6.6
TOTAL, SOUTHEASTERN UNIT	581,034	224,399	1,020,331	1,825,764	3.8
Belmont	77,079	26,376	117,780	221,235	11.1
Carroll	43,412	16,559	76,476	136,447	17.2
Coshocton	83,216	28,576	125,947	237,739	10.1
Guernsey	68,857	26,295	121,109	216,261	13.2
Harrison	58,761	16,028	70,000	144,789	14.4
Holmes	43,641	18,204	85,304	147,149	19.1
Jefferson	65,108	19,681	80,515	165,304	11.0
Monroe	102,975	52,215	238,962	394,151	8.2
Muskingum	72,495	25,230	109,568	207,294	8.5
Noble	69,318	19,008	83,922	172,249	14.0
Tuscarawas	71,915	20,748	90,757	183,419	15.0
TOTAL, EAST CENTRAL UNIT	756,777	268,919	1,200,339	2,226,035	3.7

(continued)

County and geographic unit	Poletimber	Sawtimber		Total growing stock	Sampling error
		Sawlog	Upper stem		
	thousand cubic feet				*percent*
Ashland/Richland	77,907	37,996	174,553	290,456	15.4
Ashtabula	143,614	25,790	104,714	274,118	11.7
Columbiana	58,255	19,218	83,193	160,666	15.7
Erie/Huron	46,952†	17,519†	79,848†	144,319	26.2
Geauga/Lake	90,643	29,658	129,695	249,996	13.2
Lorain/Medina	64,412	26,202	116,807	207,421	21.1
Mahoning	28,521	7,908†	35,382†	71,811	25.5
Portage/Summit	76,158	22,691	98,728	197,577	12.4
Stark/Wayne	55,506	19,957	94,738	170,201	16.2
Trumbull	72,487	19,891	87,022†	179,400	18.7
TOTAL, NORTHEASTERN UNIT	714,456	226,830	1,004,678	1,945,963	5.4
Butler/Hamilton	24,067	9,950	44,453	78,469	19.7
Clark/Darke/Miami	22,212†	12,070	58,431	92,712	17.1
Clinton/Greene/Montgomery/Preble/Warren	48,836	25,931	119,738	194,505	15.5
Fairfield/Licking	72,537	38,177	182,381	293,096	10.3
Fayette/Franklin/Madison/Pickaway	16,982†	8,418†	39,186†	64,586	29.7
TOTAL, SOUTHWESTERN UNIT	184,634	94,546	444,188	723,368	7.2
Allen/Auglaize/Mercer/Putnam/Van Wert	38,777	24,845	111,531	175,153	14.0
Champaign/Logan/Shelby/Union	55,973	14,865	69,571	140,409	17.0
Crawford/Hardin/Wyandot	34,051	25,442	122,516	182,009	13.6
Defiance/Fulton/Henry/Lucas/Paulding/Williams	74,637	21,328	98,733	194,698	13.9
Delaware/Marion/Morrow	55,013	18,536	84,719	158,268	14.5
Hancock/Ottowa/Sandusky/Seneca/Wood	58,822	21,414	94,174	174,411	12.2
Knox	47,985	19,324	94,085	161,394	15.1
TOTAL, NORTHWESTERN UNIT	365,258	145,754	675,329	1,186,341	5.4
TOTAL, ALL COUNTIES	3,277,152	1,235,457	5,583,595	10,096,205	1.9
Sampling error (percent)	2.1	2.2	2.4	1.9	

NOTE: Cell estimates with sampling errors greater than 25 percent but less than 50 percent—denoted by (†)—are suspect and should be used with caution. Those with sampling errors greater than or equal to 50 percent—denoted by (‡)—are not significantly different from zero and are unreliable.

Biomass of growing stock on timberland, by county and component, green-weight basis, Ohio, 1991

County and geographic unit	Poletimber	Sawtimber		Total growing stock	Sampling error
		Sawlog	Upper stem		
	thousand green tons				*percent*
Adams	4,188	7,687	1,722	13,598	8.5
Brown	1,966	4,259	896	7,121	16.7
Clermont	2,183	2,889	658	5,730	15.3
Gallia	4,018	3,707	857	8,583	9.5
Highland	1,692	3,049	676	5,416	15.1
Jackson	2,822	4,166	889	7,877	10.3
Lawrence	3,820	8,350	1,826	13,996	10.1
Pike	2,621	5,145	1,152	8,918	10.0
Ross	2,763	5,883	1,274	9,920	12.5
Scioto	4,750	11,451	2,524	18,726	10.7
TOTAL, SOUTH CENTRAL UNIT	30,824	56,586	12,475	99,885	3.7
Athens	3,700	7,166	1,606	12,473	8.4
Hocking/Perry	6,746	11,057	2,380	20,182	6.9
Meigs	3,436	5,645	1,322	10,403	9.1
Morgan/Washington	7,423	13,624	2,872	23,918	8.3
Vinton	4,219	7,653	1,707	13,580	6.5
TOTAL, SOUTHEASTERN UNIT	25,524	45,144	9,887	80,555	3.7
Belmont	3,599	5,663	1,258	10,520	10.6
Carroll	1,896	3,404	725	6,026	16.7
Coshocton	3,714	5,565	1,266	10,545	10.0
Guernsey	3,089	5,356	1,175	9,620	12.1
Harrison	2,719	3,012	688	6,419	13.0
Holmes	2,188	4,004	864	7,055	18.6
Jefferson	3,101	3,726	913	7,741	10.2
Monroe	4,413	9,830	2,149	16,393	7.6
Muskingum	3,368	4,780	1,093	9,242	8.7
Noble	3,003	3,633	808	7,444	13.3
Tuscarawas	3,043	3,854	880	7,776	14.3
TOTAL, EAST CENTRAL UNIT	34,133	52,827	11,820	98,779	3.5

(continued)

County and geographic unit	Poletimber	Sawtimber		Total growing stock	Sampling error
		Sawlog	Upper stem		
	thousand green tons				*percent*
Ashland/Richland	3,589	7,902	1,720	13,211	15.0
Ashtabula	6,233	4,639	1,139	12,012	11.9
Columbiana	2,642	4,030	920	7,593	15.4
Erie/Huron	1,982†	3,643†	790†	6,415	24.9
Geauga/Lake	3,842	5,677	1,286	10,805	13.0
Lorain/Medina	2,724	4,788	1,060	8,572	20.2
Mahoning	1,379†	1,641†	373†	3,393	24.5
Portage/Summit	3,487	4,416	999	8,902	11.6
Stark/Wayne	2,534	4,392	915	7,841	17.5
Trumbull	3,117	4,031	913	8,061	18.4
TOTAL, NORTHEASTERN UNIT	31,529	45,161	10,115	86,805	5.2
Butler/Hamilton	1,252	2,257	498	4,007	19.6
Clark/Darke/Miami	1,120†	2,901	593	4,614	17.6
Clinton/Greene/Montgomery/Preble/Warren	2,429	5,838	1,264	9,530	15.4
Fairfield/Licking	3,525	8,693	1,827	14,045	11.8
Fayette/Franklin/Madison/Pickaway	833†	2,002†	418†	3,253	29.2
TOTAL, SOUTHWESTERN UNIT	9,157	21,692	4,600	35,449	7.5
Allen/Auglaize/Mercer/Putnam/Van Wert	1,867	5,347	1,178	8,392	13.5
Champaign/Logan/Shelby/Union	2,760	3,310	700	6,771	16.2
Crawford/Hardin/Wyandot	1,598	5,845	1,204	8,646	13.8
Defiance/Fulton/Henry/Lucas/Paulding/Williams	3,545	4,719	1,018	9,282	14.1
Delaware/Marion/Morrow	2,602	3,941	862	7,404	14.4
Hancock/Ottowa/Sandusky/Seneca/Wood	2,648	4,532	1,016	8,196	11.5
Knox	2,144	4,145	852	7,141	15.2
TOTAL, NORTHWESTERN UNIT	17,164	31,840	6,829	55,833	5.3
TOTAL, ALL COUNTIES	148,331	253,250	55,726	457,308	1.8
Sampling error (percent)	2.1	2.3	2.2	1.8	

NOTE: Cell estimates with sampling errors greater than 25 percent but less than 50 percent – denoted by (†) – are suspect and should be used with caution. Those with sampling errors greater than or equal to 50 percent – denoted by (‡) – are not significantly different from zero and are unreliable.

Biomass of growing stock on timberland, by county and component, dry-weight basis, Ohio, 1991

County and geographic unit	Poletimber	Sawtimber: Sawlog	Sawtimber: Upper stem	Total growing stock	Sampling error
	thousand dry tons				*percent*
Adams	2,831	5,413	1,200	9,443	8.8
Brown	1,297	3,144	652	5,093	16.9
Clermont	1,433	1,938	438	3,810	15.2
Gallia	2,451	2,436	560	5,447	10.0
Highland	1,063	1,960	431	3,454	14.6
Jackson	1,807	2,888	615	5,310	10.8
Lawrence	2,377	5,599	1,212	9,188	10.5
Pike	1,777	3,519	786	6,082	10.1
Ross	1,801	4,295	921	7,017	13.1
Scioto	3,066	7,847	1,709	12,622	10.9
TOTAL, SOUTH CENTRAL UNIT	19,903	39,039	8,525	67,466	3.8
Athens	2,335	4,887	1,078	8,299	8.7
Hocking/Perry	3,930	6,852	1,466	12,249	6.9
Meigs	2,125	3,691	853	6,670	9.6
Morgan/Washington	4,499	8,887	1,862	15,248	8.5
Vinton	2,645	5,123	1,136	8,905	6.9
TOTAL, SOUTHEASTERN UNIT	15,535	29,440	6,395	51,370	3.8
Belmont	2,208	3,592	789	6,589	11.7
Carroll	1,217	2,377	501	4,095	17.1
Coshocton	2,131	3,455	776	6,362	10.3
Guernsey	1,893	3,523	768	6,184	12.4
Harrison	1,662	1,970	448	4,079	13.4
Holmes	1,285	2,431	521	4,237	19.0
Jefferson	1,980	2,359	575	4,913	10.1
Monroe	2,590	6,285	1,355	10,230	9.1
Muskingum	2,214	3,299	741	6,254	9.1
Noble	1,830	2,413	528	4,771	13.6
Tuscarawas	1,916	2,611	588	5,113	14.1
TOTAL, EAST CENTRAL UNIT	20,926	34,314	7,588	62,827	3.7

(continued)

County and geographic unit	Poletimber	Sawtimber Sawlog	Sawtimber Upper stem	Total growing stock	Sampling error
	thousand dry tons				*percent*
Ashland/Richland	2,249	4,880	1,054	8,182	14.9
Ashtabula	3,849	3,170	768	7,787	12.0
Columbiana	1,711	2,951	661	5,323	15.7
Erie/Huron	1,245†	2,539†	539†	4,323	27.2
Geauga/Lake	2,492	3,829	864	7,185	13.0
Lorain/Medina	1,576	3,129	688	5,392	20.3
Mahoning	850†	1,175†	263†	2,288	24.2
Portage/Summit	2,238	3,194	707	6,139	12.1
Stark/Wayne	1,502	3,108†	633†	5,242	20.2
Trumbull	2,010	2,943	655	5,609	18.6
TOTAL, NORTHEASTERN UNIT	19,721	30,919	6,830	57,469	5.4
Butler/Hamilton	778	1,478	323	2,579	19.5
Clark/Darke/Miami	653	2,083	419	3,155	21.3
Clinton/Greene/Montgomery/Preble/Warren	1,506	3,742	799	6,047	15.5
Fairfield/Licking	2,172	5,665	1,178	9,015	11.2
Fayette/Franklin/Madison/Pickaway	553†	1,615†	331†	2,499	32.1
TOTAL, SOUTHWESTERN UNIT	5,662	14,584	3,051	23,296	7.7
Allen/Auglaize/Mercer/Putnam/Van Wert	1,095	3,549	765	5,409	13.4
Champaign/Logan/Shelby/Union	1,664	2,315†	477	4,456	18.2
Crawford/Hardin/Wyandot	967	3,971	805	5,743	15.6
Defiance/Fulton/Henry/Lucas/Paulding/Williams	2,078	3,201	683	5,962	13.9
Delaware/Marion/Morrow	1,630	2,521	546	4,696	13.7
Hancock/Ottawa/Sandusky/Seneca/Wood	1,617	2,975	656	5,248	11.7
Knox	1,364	2,721	559	4,644	15.4
TOTAL, NORTHWESTERN UNIT	10,415	21,252	4,490	36,157	5.5
TOTAL, ALL COUNTIES	92,162	169,547	36,878	298,586	1.9
Sampling error (percent)	2.0	2.4	2.2	1.9	

NOTE: Cell estimates with sampling errors greater than 25 percent but less than 50 percent—denoted by (†)—are suspect and should be used with caution. Those with sampling errors greater than or equal to 50 percent—denoted by (‡)—are not significantly different from zero and are unreliable.

Biomass of evergreen timber on timberland, by county, class of timber, and component, Ohio, 1991

County and geographic unit	Growing-stock trees: Growing stock	Growing-stock trees: Branches	Growing-stock trees: Foliage	Growing-stock trees: Stump and roots	Cull trees	Total timber	Sampling error
	thousand dry tons						percent
Adams	417†	78†	58†	141†	42†	736	30.8
Brown	30†	6†	4‡	10†	0	49	49.7
Clermont	51‡	10‡	8‡	17‡	16‡	101	54.8
Gallia	443†	82†	61†	149†	8‡	743	30.6
Highland	9‡	2‡	1‡	3‡	0	15	100.0
Jackson	545†	101†	70†	182†	43‡	941	36.8
Lawrence	170‡	31‡	22‡	57‡	0	280	84.9
Pike	114‡	21‡	15‡	38‡	0	188	77.2
Ross	76‡	14‡	9‡	25‡	0	124	55.6
Scioto	125†	23†	16†	42†	0	206	43.0
TOTAL, SOUTH CENTRAL UNIT	1,976	368	265	665	108	3,384	16.6
Athens	64‡	12‡	8‡	21‡	0	105	54.7
Hocking/Perry	501†	93†	64†	167†	8‡	833	42.1
Meigs	224†	41†	30†	75†	6‡	375	35.4
Morgan/Washington	333†	62†	45†	113†	21‡	573	29.5
Vinton	327‡	61‡	43‡	110‡	0	540	52.4
TOTAL, SOUTHEASTERN UNIT	1,448	269	189	485	35‡	2,426	20.7
Belmont	32‡	6‡	5‡	11‡	0	54	89.6
Carroll	0	0	0	0	0	0	0.0
Coshocton	174‡	32‡	22‡	58‡	0	287	58.7
Guernsey	369‡	68‡	48‡	124‡	5‡	614	53.3
Harrison	134‡	25‡	18‡	45‡	0	221	65.3
Holmes	107‡	20‡	13‡	36‡	0	176	100.0
Jefferson	21‡	4‡	3‡	7‡	0	35	71.8
Monroe	413‡	77‡	55‡	139‡	0	683	53.3
Muskingum	0	0	0	0	0	0	0.0
Noble	242‡	45‡	35‡	82‡	0	404	100.0
Tuscarawas	57‡	11‡	9‡	19‡	0	96	66.2
TOTAL, EAST CENTRAL UNIT	1,548†	288†	207†	520†	5‡	2,568	27.2

(continued)

County and geographic unit	Growing-stock trees				Cull trees	Total timber	Sampling error
	Growing stock	Branches	Foliage	Stump and roots			
	thousand dry tons						*percent*
Ashland/Richland	83‡	16‡	12‡	28‡	18‡	157	67.6
Ashtabula	104‡	19‡	14‡	35‡	1‡	174	56.6
Columbiana	89†	16†	12†	30†	0	147	45.4
Erie/Huron	0	0	0	0	0	0	0.0
Geauga/Lake	44‡	8‡	6‡	15‡	0	73	60.7
Lorain/Medina	28‡	5‡	4‡	9‡	0	47	100.0
Mahoning	132‡	25‡	17‡	44‡	0	218	71.6
Portage/Summit	0	0	0	0	0	0	0.0
Stark/Wayne	92‡	17‡	13‡	31‡	6‡	160	72.4
Trumbull	70‡	13‡	10‡	24‡	0	116	91.5
TOTAL, NORTHEASTERN UNIT	643†	120†	87†	217†	26‡	1,092	25.7
Butler/Hamilton	3‡	1‡	0‡	1‡	6‡	11	60.8
Clark/Darke/Miami	0	0	0	0	0	0	0.0
Clinton/Greene/Montgomery/Preble/Warren	22‡	4‡	3‡	8‡	0	37	63.9
Fairfield/Licking	345‡	64‡	44‡	115‡	65‡	633	52.9
Fayette/Franklin/Madison/Pickaway	0	0	0	0	0	0	0.0
TOTAL, SOUTHWESTERN UNIT	370†	69†	48†	124†	71‡	682	49.3
Allen/Auglaize/Mercer/Putnam/Van Wert	0	0	0	0	0	0	0.0
Champaign/Logan/Shelby/Union	39‡	7‡	6‡	13‡	0	65	100.0
Crawford/Hardin/Wyandot	0	0	0	0	0	0	0.0
Defiance/Fulton/Henry/Lucas/Paulding/Williams	135‡	25‡	17‡	45‡	0	222	89.3
Delaware/Marion/Morrow	18‡	3‡	2‡	6‡	0	30	100.0
Hancock/Ottowa/Sandusky/Seneca/Wood	0	0	0	0	0	0	0.0
Knox	258‡	48‡	34‡	87‡	0	427	67.0
TOTAL, NORTHWESTERN UNIT	450†	84†	59†	151†	0	744	47.8
TOTAL, ALL COUNTIES	6,437	1,196	856	2,163	244	10,896	10.8
Sampling error (percent)	10.8	10.8	10.8	10.8	32.4	10.8	

NOTE: Cell estimates with sampling errors greater than 25 percent but less than 50 percent—denoted by (†)—are suspect and should be used with caution. Those with sampling errors greater than or equal to 50 percent—denoted by (‡)—are not significantly different from zero and are unreliable.

Biomass of deciduous timber on timberland, by county, class of timber, and component, Ohio, 1991

County and geographic unit	Growing-stock trees: Growing stock	Growing-stock trees: Branches	Growing-stock trees: Foliage	Growing-stock trees: Stump and roots	Cull trees	Total timber	Sampling error
	thousand dry tons						*percent*
Adams	9,026	1,017	274	2,576	707	13,601	9.4
Brown	5,063	555	144	1,415	665†	7,842	16.1
Clermont	3,759	430	119	1,084	705†	6,096	15.1
Gallia	5,005	584	165	1,464	378†	7,597	11.0
Highland	3,445	391	107	989	436†	5,368	14.0
Jackson	4,766	545	150	1,376	598	7,435	11.7
Lawrence	9,018	1,007	268	2,557	437	13,288	10.1
Pike	5,968	675	183	1,709	558	9,094	10.1
Ross	6,941	772	205	1,962	595	10,474	12.3
Scioto	12,497	1,395	371	3,544	784†	18,591	10.2
TOTAL, SOUTH CENTRAL UNIT	65,489	7,373	1,987	18,675	5,864	99,387	3.8
Athens	8,235	927	249	2,348	487†	12,247	8.2
Hocking/Perry	11,747	1,334	364	3,372	1,045	17,864	6.6
Meigs	6,446	734	201	1,854	580†	9,814	10.0
Morgan/Washington	14,915	1,662	442	4,217	1,511	22,746	8.2
Vinton	8,578	973	265	2,462	403	12,682	7.5
TOTAL, SOUTHEASTERN UNIT	49,922	5,630	1,521	14,252	4,027	75,352	3.7
Belmont	6,557	745	204	1,883	487	9,875	11.3
Carroll	4,095	457	122	1,160	343†	6,177	16.6
Coshocton	6,187	705	194	1,781	587†	9,454	10.0
Guernsey	5,815	658	179	1,665	677†	8,995	13.1
Harrison	3,945	456	128	1,147	462†	6,139	13.9
Holmes	4,130	465	126	1,178	533†	6,432	18.3
Jefferson	4,892	568	160	1,427	707	7,754	8.7
Monroe	9,817	1,091	288	2,773	730†	14,699	8.9
Muskingum	6,254	712	195	1,797	939	9,897	8.2
Noble	4,529	513	140	1,295	256†	6,733	15.1
Tuscarawas	5,056	579	160	1,461	349†	7,605	14.0
TOTAL, EAST CENTRAL UNIT	61,279	6,951	1,895	17,566	6,069	93,760	3.6

(continued)

County and geographic unit	Growing-stock trees				Cull trees	Total timber	Sampling error
	Growing stock	Branches	Foliage	Stump and roots			
	thousand dry tons						*percent*
Ashland/Richland	8,099	906	242	2,298	703†	12,248	14.6
Ashtabula	7,683	906	261	2,265	877†	11,991	12.0
Columbiana	5,235	591	160	1,496	556	8,039	14.4
Erie/Huron	4,323†	481†	128†	1,221†	624†	6,776	24.8
Geauga/Lake	7,141	813	223	2,051	467†	10,695	13.0
Lorain/Medina	5,364	601	161	1,524	406†	8,056	20.0
Mahoning	2,155	247	68	622	106‡	3,198	23.2
Portage/Summit	6,139	695	189	1,754	1,450‡	10,227	14.7
Stark/Wayne	5,150	567	148	1,441	522†	7,828	18.9
Trumbull	5,539	632	174	1,594	372	8,310	18.5
TOTAL, NORTHEASTERN UNIT	56,826	6,437	1,752	16,267	6,084	87,366	5.3
Butler/Hamilton	2,576	287	77	730	618†	4,289	18.8
Clark/Darke/Miami	3,155	341	86	872	664†	5,119	19.9
Clinton/Greene/Montgomery/Preble/Warren	6,025	666	175	1,694	1,121	9,680	14.2
Fairfield/Licking	8,670	958	251	2,438	1,382	13,699	12.5
Fayette/Franklin/Madison/Pickaway	2,499†	271†	69†	693†	476‡	4,008	29.6
TOTAL, SOUTHWESTERN UNIT	22,926	2,524	658	6,426	4,260	36,795	7.7
Allen/Auglaize/Mercer/Putnam/Van Wert	5,409	591	152	1,507	402†	8,060	12.8
Champaign/Logan/Shelby/Union	4,417	496	134	1,255	808†	7,110	16.8
Crawford/Hardin/Wyandot	5,743	619	156	1,585	258†	8,361	15.3
Defiance/Fulton/Henry/Lucas/Paulding/Williams	5,827	659	179	1,666	501†	8,833	13.5
Delaware/Marion/Morrow	4,678	529	144	1,338	1,208†	7,898	14.9
Hancock/Ottowa/Sandusky/Seneca/Wood	5,248	588	157	1,489	1,297†	8,780	12.4
Knox	4,385	492	132	1,246	409	6,664	15.6
TOTAL, NORTHWESTERN UNIT	35,707	3,974	1,054	10,087	4,883	55,705	5.4
TOTAL, ALL COUNTIES	292,149	32,889	8,867	83,274	31,186	448,365	1.9
Sampling error (percent)	2.0	1.9	1.8	1.9	5.2	1.9	

NOTE: Cell estimates with sampling errors greater than 25 percent but less than 50 percent—denoted by (†)—are suspect and should be used with caution. Those with sampling errors greater than or equal to 50 percent—denoted by (‡)—are not significantly different from zero and are unreliable.

Biomass of all timber on timberland, by county, class of timber, and component, Ohio, 1991

County and geographic unit	Growing-stock trees: Growing stock	Growing-stock trees: Branches	Growing-stock trees: Foliage	Growing-stock trees: Stump and roots	Cull trees	Total timber	Sampling error
	thousand dry tons						percent
Adams	9,443	1,095	333	2,717	748	14,337	8.7
Brown	5,093	561	148	1,425	665†	7,891	16.0
Clermont	3,810	439	126	1,101	720†	6,197	14.7
Gallia	5,447	666	226	1,614	386†	8,340	9.3
Highland	3,454	393	108	992	436†	5,383	13.8
Jackson	5,310	646	221	1,558	641	8,376	10.0
Lawrence	9,188	1,039	290	2,614	437	13,568	9.9
Pike	6,082	696	198	1,747	558	9,282	9.7
Ross	7,017	786	214	1,987	595	10,599	12.3
Scioto	12,622	1,419	387	3,586	784†	18,798	10.0
TOTAL, SOUTH CENTRAL UNIT	67,466	7,741	2,252	19,340	5,971	102,771	3.6
Athens	8,299	938	258	2,369	487†	12,352	8.1
Hocking/Perry	12,249	1,427	428	3,540	1,054	18,697	6.4
Meigs	6,670	775	231	1,929	585†	10,189	9.4
Morgan/Washington	15,248	1,724	486	4,329	1,532	23,319	8.0
Vinton	8,905	1,034	308	2,571	403	13,221	6.6
TOTAL, SOUTHEASTERN UNIT	51,370	5,899	1,710	14,738	4,062	77,778	3.5
Belmont	6,589	751	208	1,894	487	9,929	11.2
Carroll	4,095	457	122	1,160	343†	6,177	16.6
Coshocton	6,362	738	216	1,839	587†	9,741	9.8
Guernsey	6,184	727	227	1,789	682†	9,608	12.5
Harrison	4,079	481	146	1,192	462†	6,360	13.3
Holmes	4,237	485	139	1,214	533†	6,608	17.6
Jefferson	4,913	572	163	1,434	707	7,789	8.7
Monroe	10,230	1,168	343	2,911	730†	15,382	8.1
Muskingum	6,254	712	195	1,797	939	9,897	8.2
Noble	4,771	558	175	1,377	256†	7,137	13.1
Tuscarawas	5,113	590	169	1,480	349†	7,701	13.8
TOTAL, EAST CENTRAL UNIT	62,827	7,239	2,102	18,087	6,073	96,329	3.5

(continued)

County and geographic unit	Growing-stock trees: Growing stock	Branches	Foliage	Stump and roots	Cull trees	Total timber	Sampling error
	thousand dry tons						percent
Ashland/Richland	8,182	921	253	2,326	721†	12,404	14.3
Ashtabula	7,787	925	275	2,300	878†	12,166	11.8
Columbiana	5,323	608	172	1,526	556	8,186	14.4
Erie/Huron	4,323†	481†	128†	1,221†	624†	6,776	24.8
Geauga/Lake	7,185	821	229	2,066	467†	10,768	13.0
Lorain/Medina	5,392	606	165	1,533	406†	8,102	20.1
Mahoning	2,288	271	85†	666	106‡	3,416	23.5
Portage/Summit	6,139	695	189	1,754	1,450‡	10,227	14.7
Stark/Wayne	5,242	584	161	1,473	528†	7,988	18.4
Trumbull	5,609	645	184	1,618	372	8,426	18.3
TOTAL, NORTHEASTERN UNIT	57,469	6,557	1,840	16,483	6,110	88,459	5.2
Butler/Hamilton	2,579	288	77	731	624†	4,300	18.8
Clark/Darke/Miami	3,155	341	86	872	664†	5,119	19.9
Clinton/Greene/Montgomery/Preble/Warren	6,047	670	178	1,701	1,121	9,717	14.0
Fairfield/Licking	9,015	1,022	295	2,553	1,446	14,332	11.5
Fayette/Franklin/Madison/Pickaway	2,499†	271†	69†	693†	476‡	4,008	29.6
TOTAL, SOUTHWESTERN UNIT	23,296	2,593	706	6,550	4,331	37,477	7.4
Allen/Auglaize/Mercer/Putnam/Van Wert	5,409	591	152	1,507	402†	8,060	12.8
Champaign/Logan/Shelby/Union	4,456	503	139	1,268	808†	7,175	16.8
Crawford/Hardin/Wyandot	5,743	619	156	1,585	258†	8,361	15.3
Defiance/Fulton/Henry/Lucas/Paulding/Williams	5,962	684	197	1,711	501†	9,055	13.0
Delaware/Marion/Morrow	4,696	533	146	1,344	1,208†	7,927	14.8
Hancock/Ottowa/Sandusky/Seneca/Wood	5,248	588	157	1,489	1,297†	8,780	12.4
Knox	4,644	540	166	1,333	409	7,091	14.2
TOTAL, NORTHWESTERN UNIT	36,157	4,058	1,113	10,238	4,883	56,449	5.3
TOTAL, ALL COUNTIES	298,586	34,085	9,723	85,437	31,430	459,261	1.8
Sampling error (percent)	1.9	1.8	1.8	1.9	5.2	1.8	

NOTE: Cell estimates with sampling errors greater than 25 percent but less than 50 percent—denoted by (†)—are suspect and should be used with caution. Those with sampling errors greater than or equal to 50 percent—denoted by (‡)—are not significantly different from zero and are unreliable.

Biomass of evergreen trees and shrubs on timberland, by county and class of material, Ohio, 1991

County and geographic unit	Timber	Nontimber: Salvable dead trees	Nontimber: Saplings	Nontimber: Seedlings	Shrubs	Total trees and shrubs	Sampling error
	thousand dry tons						percent
Adams	736[†]	0	334[†]	8[†]	0	1,078	25.6
Brown	49[†]	0	16[‡]	1[‡]	0	66	48.3
Clermont	101[‡]	0	81[‡]	1[‡]	0	184	45.5
Gallia	743[†]	31[‡]	165[†]	2[‡]	0	942	29.5
Highland	15[‡]	0	0	0	0	16	94.5
Jackson	941[†]	26[†]	40[‡]	0	0	1,008	35.6
Lawrence	280[‡]	24[‡]	28[‡]	3[‡]	0	335	78.4
Pike	188[‡]	2[‡]	60[‡]	1[‡]	0	250	62.8
Ross	124[‡]	3[‡]	5[‡]	0	0	132	53.4
Scioto	206[†]	5[‡]	6[‡]	1[‡]	0	219	40.5
TOTAL, SOUTH CENTRAL UNIT	3,384	92[†]	736	17	0	4,229	14.9
Athens	105[‡]	1[‡]	7[‡]	0	0	112	56.1
Hocking/Perry	833[†]	14[‡]	63[‡]	1[‡]	0	911	39.4
Meigs	375[†]	3[‡]	17[‡]	4[‡]	0	400	34.5
Morgan/Washington	573[†]	15[‡]	74[‡]	2[‡]	0	664	28.5
Vinton	540[‡]	0	79[†]	0	0	620	49.7
TOTAL, SOUTHEASTERN UNIT	2,426	32[†]	241[†]	8[†]	0	2,707	19.6
Belmont	54[‡]	0	19[‡]	0	0	73	84.0
Carroll	0	0	3[‡]	0	0	3	91.1
Coshocton	287[‡]	0	11[‡]	0	0	298	56.9
Guernsey	614[‡]	20[‡]	3[‡]	0	0	637	52.4
Harrison	221[‡]	0	36[‡]	0	0	257	68.0
Holmes	176[‡]	0	1[‡]	0	0	176	100.0
Jefferson	35[‡]	0	9[‡]	0	0	44	70.1
Monroe	683[‡]	9[‡]	49[‡]	0	0	741	50.8
Muskingum	0	0	1[‡]	0	0	1	100.0
Noble	404[‡]	0	35[‡]	0	0	439	100.0
Tuscarawas	96[‡]	0	19[‡]	0	0	115	67.9
TOTAL, EAST CENTRAL UNIT	2,568[†]	28[‡]	185[†]	0	0	2,783	26.6

(continued)

County and geographic unit	Timber	Nontimber: Salvable dead trees	Nontimber: Saplings	Nontimber: Seedlings	Shrubs	Total trees and shrubs	Sampling error
	thousand dry tons						percent
Ashland/Richland	157‡	0	0	0	0	157	67.6
Ashtabula	174‡	11‡	9‡	0	0	195	53.6
Columbiana	147†	0	38‡	0	0	185	50.9
Erie/Huron	0	0	0	0	0	0	0.0
Geauga/Lake	73‡	0	30‡	0	0	102	57.5
Lorain/Medina	47‡	9‡	0	0	0	56	100.0
Mahoning	218‡	10‡	6‡	0	0	234	72.3
Portage/Summit	0	0	1‡	0	0	1	100.0
Stark/Wayne	160‡	0	0	0	0	160	72.4
Trumbull	116‡	0	24‡	0	0	140	81.9
TOTAL, NORTHEASTERN UNIT	1,092†	30‡	107†	1‡	0	1,230	24.8
Butler/Hamilton	11‡	0	4‡	0	0	15	62.3
Clark/Darke/Miami	0	0	0	0	0	0	0.0
Clinton/Greene/Montgomery/Preble/Warren	37‡	0	19‡	0	0	57	67.3
Fairfield/Licking	633‡	0	21‡	1‡	0	655	51.4
Fayette/Franklin/Madison/Pickaway	0	0	1	0	0	1	100.0
TOTAL, SOUTHWESTERN UNIT	682†	0	44‡	1‡	0	728	46.6
Allen/Auglaize/Mercer/Putnam/Van Wert	0	0	0	0	0	0	0.0
Champaign/Logan/Shelby/Union	65‡	0	13‡	0	0	78	84.5
Crawford/Hardin/Wyandot	0	0	0	0	0	0	0.0
Defiance/Fulton/Henry/Lucas/Paulding/Williams	222‡	0	6‡	0	0	229	87.2
Delaware/Marion/Morrow	30‡	0	0	0	0	30	100.0
Hancock/Ottawa/Sandusky/Seneca/Wood	0	0	0	0	0	0	90.9
Knox	427‡	1‡	0	0	0	428	67.0
TOTAL, NORTHWESTERN UNIT	744†	1‡	19‡	0	0	764	46.7
TOTAL, ALL COUNTIES	10,896	184	1,332	28	1	12,441	10.8
Sampling error (percent)	10.8	23.7	14.1	18.6	36.8	10.0	

NOTE: Cell estimates with sampling errors greater than 25 percent but less than 50 percent—denoted by (†)—are suspect and should be used with caution. Those with sampling errors greater than or equal to 50 percent—denoted by (‡)—are not significantly different from zero and are unreliable.

Biomass of deciduous trees and shrubs on timberland, by county and class of material, Ohio, 1991

County and geographic unit	Timber	Nontimber: Salvable dead trees	Nontimber: Saplings	Nontimber: Seedlings	Shrubs	Total trees and shrubs	Sampling error
	thousand dry tons						*percent*
Adams	13,601	121†	1,081	322	140	15,265	8.5
Brown	7,842	77†	582	89	33†	8,622	15.4
Clermont	6,096	73†	495	115	43	6,822	14.3
Gallia	7,597	96†	909	208	74	8,883	9.4
Highland	5,368	78†	444†	89	23†	6,001	13.3
Jackson	7,435	89†	1,003	174	141†	8,842	10.4
Lawrence	13,288	144†	1,430	240	143	15,246	8.5
Pike	9,094	132†	1,084	226	81†	10,616	8.0
Ross	10,474	107†	862	170	65	11,678	11.9
Scioto	18,591	87†	1,492	364	165	20,699	8.6
TOTAL, SOUTH CENTRAL UNIT	99,387	1,004	9,381	1,995	908	112,674	3.3
Athens	12,247	320†	1,258	173	147	14,145	7.5
Hocking/Perry	17,864	119†	2,092	317	184	20,576	5.9
Meigs	9,814	122†	991	210	152	11,289	9.3
Morgan/Washington	22,746	281†	2,243	462	286	26,018	7.5
Vinton	12,682	57†	1,266	251	68	14,323	6.4
TOTAL, SOUTHEASTERN UNIT	75,352	899	7,850	1,413	837	86,350	3.3
Belmont	9,875	63†	950	104	79†	11,072	10.4
Carroll	6,177	29†	658	140	122	7,126	15.1
Coshocton	9,454	110†	1,207	118	104	10,992	9.2
Guernsey	8,995	69†	1,055	179	112	10,409	12.3
Harrison	6,139	119†	804	151	74	7,287	12.5
Holmes	6,432	78†	482†	38†	70†	7,100	17.1
Jefferson	7,754	53†	861	95	60†	8,822	7.9
Monroe	14,699	102†	1,083	186	251	16,322	7.8
Muskingum	9,897	59†	1,391	190	187	11,724	7.5
Noble	6,733	40†	738	153	138	7,801	14.0
Tuscarawas	7,605	438†	862	157	89	9,151	13.9
TOTAL, EAST CENTRAL UNIT	93,760	1,161†	10,092	1,510	1,284	107,807	3.4

(continued)

County and geographic unit	Timber	Nontimber			Shrubs	Total trees and shrubs	Sampling error
		Salvable dead trees	Saplings	Seedlings			
	thousand dry tons						*percent*
Ashland/Richland	12,248	84†	673	131†	56†	13,191	14.1
Ashtabula	11,991	66†	1,907	309	196†	14,468	9.9
Columbiana	8,039	33‡	894	138	78†	9,181	12.2
Erie/Huron	6,776	77†	440†	47†	32†	7,372	23.6
Geauga/Lake	10,695	117†	1,050	124	87†	12,073	12.7
Lorain/Medina	8,056	357†	952	78	166	9,609	18.2
Mahoning	3,198	14‡	481†	62†	34‡	3,790	21.4
Portage/Summit	10,227	75†	948	235†	219†	11,703	13.5
Stark/Wayne	7,828	59†	630	108†	98†	8,723	17.5
Trumbull	8,310	33‡	801	125	171†	9,439	16.8
TOTAL, NORTHEASTERN UNIT	87,366	915	8,777	1,356	1,135	99,550	4.8
Butler/Hamilton	4,289	54†	379	64†	23†	4,809	18.0
Clark/Darke/Miami	5,119	57‡	466†	82†	20†	5,745	18.5
Clinton/Greene/Montgomery/Preble/Warren	9,680	118†	709	170	71	10,747	13.4
Fairfield/Licking	13,699	147†	1,343	180	113†	15,482	12.0
Fayette/Franklin/Madison/Pickaway	4,008†	12‡	284†	43†	26†	4,374	28.3
TOTAL, SOUTHWESTERN UNIT	36,795	389	3,182	538	254	41,157	7.3
Allen/Auglaize/Mercer/Putnam/Van Wert	8,060	42‡	551	87	45‡	8,785	12.3
Champaign/Logan/Shelby/Union	7,110	55‡	787	124	107	8,184	15.8
Crawford/Hardin/Wyandot	8,361	130‡	424	57†	5‡	8,977	15.2
Defiance/Fulton/Henry/Lucas/Paulding/Williams	8,833	72†	754	148	78†	9,885	13.3
Delaware/Marion/Morrow	7,898	228	853	88	70†	9,138	13.6
Hancock/Ottawa/Sandusky/Seneca/Wood	8,780	111†	888	132	81†	9,991	11.6
Knox	6,664	60‡	692	62†	100‡	7,577	13.9
TOTAL, NORTHWESTERN UNIT	55,705	699	4,950	697	486	62,536	5.2
TOTAL, ALL COUNTIES	448,365	5,066	44,231	7,508	4,904	510,074	1.7
Sampling error (percent)	1.9	9.8	2.3	2.5	4.4	1.7	

NOTE: Cell estimates with sampling errors greater than 25 percent but less than 50 percent—denoted by (†)—are suspect and should be used with caution. Those with sampling errors greater than or equal to 50 percent—denoted by (‡)—are not significantly different from zero and are unreliable.

Biomass of all trees and shrubs on timberland, by county and class of material, Ohio, 1991

County and geographic unit	Timber	Nontimber: Salvable dead trees	Nontimber: Saplings	Nontimber: Seedlings	Shrubs	Total trees and shrubs	Sampling error
	thousand dry tons						percent
Adams	14,337	121†	1,415	330	140	16,343	7.8
Brown	7,891	77‡	598	89	33†	8,688	15.2
Clermont	6,197	73†	577	116	43	7,006	13.7
Gallia	8,340	127†	1,074	210	74	9,825	8.0
Highland	5,383	78‡	444†	89	23†	6,017	13.1
Jackson	8,376	115	1,042	174	141†	9,850	9.0
Lawrence	13,568	169†	1,459	242	143	15,581	8.3
Pike	9,282	134†	1,144	226	81†	10,867	7.6
Ross	10,599	110†	866	170	65	11,810	11.9
Scioto	18,798	92†	1,498	365	165	20,918	8.5
TOTAL, SOUTH CENTRAL UNIT	102,771	1,096	10,117	2,012	908	116,904	3.2
Athens	12,352	320†	1,267	173	147	14,260	7.5
Hocking/Perry	18,697	133†	2,155	318	184	21,487	5.7
Meigs	10,189	126†	1,008	214	152	11,689	8.8
Morgan/Washington	23,319	296†	2,317	464	286	26,683	7.3
Vinton	13,221	57†	1,345	252	68	14,943	5.6
TOTAL, SOUTHEASTERN UNIT	77,778	931	8,093	1,420	837	89,060	3.2
Belmont	9,929	63†	969	104	80†	11,145	10.3
Carroll	6,177	29‡	661	140	122	7,129	15.1
Coshocton	9,741	110†	1,220	118	104	11,292	9.0
Guernsey	9,608	89†	1,058	179	112	11,046	11.6
Harrison	6,360	119‡	840	151	74	7,544	12.0
Holmes	6,608	78‡	483†	38†	70†	7,276	16.5
Jefferson	7,789	53†	871	95	60†	8,867	7.9
Monroe	15,382	111†	1,133	186	251	17,062	7.0
Muskingum	9,897	59†	1,391	190	187	11,724	7.5
Noble	7,137	40†	773	153	138	8,241	12.2
Tuscarawas	7,701	438‡	881	157	89	9,266	13.8
TOTAL, EAST CENTRAL UNIT	96,329	1,189†	10,279	1,510	1,284	110,591	3.2

(continued)

County and geographic unit	Timber	Nontimber			Shrubs	Total trees and shrubs	Sampling error
		Salvable dead trees	Saplings	Seedlings			
	thousand dry tons						*percent*
Ashland/Richland	12,404	84†	673	131†	56†	13,348	13.8
Ashtabula	12,166	77†	1,916	309	196†	14,663	9.7
Columbiana	8,186	33‡	932	138	78†	9,367	12.3
Erie/Huron	6,776	77†	440†	47†	32†	7,372	23.6
Geauga/Lake	10,768	117†	1,080	124	87†	12,176	12.7
Lorain/Medina	8,102	367†	952	78	166	9,665	18.2
Mahoning	3,416	24‡	487†	62†	34‡	4,023	21.6
Portage/Summit	10,227	75†	950	235†	219†	11,705	13.5
Stark/Wayne	7,988	59†	630	108†	98†	8,883	17.1
Trumbull	8,426	33‡	824	125	171†	9,579	16.6
TOTAL, NORTHEASTERN UNIT	88,459	945	8,884	1,357	1,135	100,780	4.8
Butler/Hamilton	4,300	54†	383†	64†	23†	4,824	18.0
Clark/Darke/Miami	5,119	57‡	466†	82†	20†	5,745	18.5
Clinton/Greene/Montgomery/Preble/Warren	9,717	118†	729	170	71†	10,804	13.2
Fairfield/Licking	14,332	147†	1,364	181	113†	16,138	11.2
Fayette/Franklin/Madison/Pickaway	4,008†	12‡	285†	43†	26†	4,375	28.3
TOTAL, SOUTHWESTERN UNIT	37,477	389	3,226	539	254	41,885	7.0
Allen/Auglaize/Mercer/Putnam/Van Wert	8,060	42‡	551	87	45‡	8,785	12.3
Champaign/Logan/Shelby/Union	7,175	55‡	800	124	107	8,261	15.7
Crawford/Hardin/Wyandot	8,361	130‡	424	57†	5‡	8,977	15.2
Defiance/Fulton/Henry/Lucas/Paulding/Williams	9,055	72†	760	148	78†	10,113	12.9
Delaware/Marion/Morrow	7,927	228	853	88	70†	9,167	13.5
Hancock/Ottawa/Sandusky/Seneca/Wood	8,780	111†	888	132	81†	9,991	11.6
Knox	7,091	61‡	692	62†	100‡	8,005	12.7
TOTAL, NORTHWESTERN UNIT	56,449	700	4,969	697	486	63,300	5.1
TOTAL, ALL COUNTIES	459,261	5,250	45,568	7,536	4,904	522,520	1.7
Sampling error (percent)	1.8	9.5	2.3	2.5	4.4	1.7	

NOTE: Cell estimates with sampling errors greater than 25 percent but less than 50 percent—denoted by (†)—are suspect and should be used with caution. Those with sampling errors greater than or equal to 50 percent—denoted by (‡)—are not significantly different from zero and are unreliable.

Area and biomass of all trees and shrubs on forest land, by county and land class, Ohio, 1991

County and geographic unit	Timberland Area	Timberland Biomass	Other forest land [a] Area	Other forest land [a] Biomass	Total forest land Area	Total forest land Biomass
	acres	thousand dry tons	acres	thousand dry tons	acres	thousand dry tons
Adams	236,315	16,343	456	32	236,771	16,375
Brown	107,845	8,688	10	1	107,855	8,689
Clermont	107,833	7,006	8,787	672	116,620	7,678
Gallia	184,553	9,825	0	0	184,553	9,825
Highland	85,308	6,017	2,611	184	87,919	6,201
Jackson	166,029	9,850	1,653	98	167,682	9,948
Lawrence	225,693	15,581	44	3	225,737	15,584
Pike	178,515	10,867	702	43	179,217	10,910
Ross	164,014	11,810	3,993	288	168,007	12,098
Scioto	280,937	20,918	477	36	281,414	20,954
TOTAL, SOUTH CENTRAL UNIT	1,737,041	116,904	18,733	1,356	1,755,774	118,260
Athens	203,255	14,260	2,912	204	206,167	14,464
Hocking/Perry	326,711	21,487	4,659	88	331,370	21,575
Meigs	194,712	11,689	1,345	186	196,057	11,875
Morgan/Washington	394,714	26,683	5,968	315	400,682	26,998
Vinton	205,076	14,943	3,095	435	208,171	15,378
TOTAL, SOUTHEASTERN UNIT	1,324,468	89,060	17,979	1,228	1,342,447	90,288
Belmont	179,069	11,145	3,262	206	182,331	11,351
Carroll	112,029	7,129	65	4	112,094	7,133
Coshocton	169,155	11,292	100	7	169,255	11,299
Guernsey	182,525	11,046	1,235	75	183,760	11,121
Harrison	156,152	7,544	75	4	156,227	7,548
Holmes	80,999	7,276	1,400	126	82,399	7,402
Jefferson	150,147	8,867	940	56	151,087	8,923
Monroe	204,005	17,062	0	0	204,005	17,062
Muskingum	210,764	11,724	3,240	180	214,004	11,904
Noble	134,289	8,241	1,130	69	135,419	8,310
Tuscarawas	157,522	9,266	2,712	20	160,234	9,286
TOTAL, EAST CENTRAL UNIT	1,736,654	110,591	14,158	746	1,750,812	111,337

(continued)

County and geographic unit	Timberland		Other forest land[a]		Total forest land	
	Area	Biomass	Area	Biomass	Area	Biomass
	acres	*thousand dry tons*	*acres*	*thousand dry tons*	*acres*	*thousand dry tons*
Ashland/Richland	149,491	13,348	1,732	155	151,223	13,503
Ashtabula	225,736	14,663	3,570	232	229,306	14,895
Columbiana	144,721	9,367	2,303	149	147,024	9,516
Erie/Huron	68,120	7,372	3,392	367	71,512	7,739
Geauga/Lake	153,501	12,176	31,624	2,419	185,125	14,595
Lorain/Medina	117,055	9,665	9,207	907	126,262	10,572
Mahoning	58,489	4,023	4,836	520	63,325	4,543
Portage/Summit	192,508	11,705	21,746	1,407	214,254	13,112
Stark/Wayne	113,671	8,883	6,771	327	120,442	9,210
Trumbull	139,217	9,579	299	21	139,516	9,600
TOTAL, NORTHEASTERN UNIT	1,362,509	100,780	85,479	6,503	1,447,988	107,283
Butler/Hamilton	87,351	4,824	17,958	1,106	105,309	5,930
Clark/Darke/Miami	74,409	5,745	2,546	197	76,955	5,942
Clinton/Greene/Montgomery/Preble/Warren	174,889	10,804	8,931	552	183,820	11,356
Fairfield/Licking	206,381	16,138	10,060	650	216,441	16,788
Fayette/Franklin/Madison/Pickaway	66,265	4,375	1,169	77	67,434	4,452
TOTAL, SOUTHWESTERN UNIT	609,295	41,885	40,664	2,582	649,959	44,467
Allen/Auglaize/Mercer/Putnam/Van Wert	95,743	8,785	14,194	597	109,937	9,382
Champaign/Logan/Shelby/Union	151,272	8,261	2,624	143	153,896	8,404
Crawford/Hardin/Wyandot	71,080	8,977	327	41	71,407	9,018
Defiance/Fulton/Henry/Lucas/Paulding/Williams	120,562	10,113	9,157	867	129,719	10,980
Delaware/Marion/Morrow	126,352	9,167	4,122	299	130,474	9,466
Hancock/Ottawa/Sandusky/Seneca/Wood	134,602	9,991	25,674	1,906	160,276	11,897
Knox	97,841	8,005	35	3	97,876	8,008
TOTAL, NORTHEASTERN UNIT	797,452	63,300	56,133	3,856	853,585	67,156
TOTAL, ALL COUNTIES	7,567,419	522,520	233,146	16,271	7,800,565	538,791

[a] Does not include 4,865,267 dry tons on 48,577 acres of urban forest land and 411,642 dry tons on 5,346 acres of productive-reserved forest land in Cuyahoga County; or biomass on 9,626 acres in Christmas tree production.

Improving Accuracy of Biomass Estimates

As mentioned previously, the validity of estimates is judged by their accuracy and precision. Precision relates to how well the population is sampled to reduce variation of sample means. This is reflected by sampling error. Precision of an estimate can be improved primarily by increasing sample size.

To increase accuracy, procedural techniques must be improved that provide estimates closer to the true mean of the population. We have presented techniques that we use to develop our biomass estimates. We can say with confidence that these procedures give us as accurate an estimate as possible using the tools available and operating under current restrictions.

One important source of bias that affects nearly all biomass estimates is the kinds of trees upon which prediction equations are based. In most cases, these equations are developed from dominant and codominant trees. Very few suppressed and cull trees in the forest understory are sampled when researchers develop prediction equations for biomass. Consequently, when applied over extensive areas, most biomass statistics probably overestimate the resource.

During our annual statewide surveys, Forest Inventory and Analysis field crews collect information on individual-tree crown class. This information could be used to apply form-specific prediction equations or factors that adjust predicative estimates, if they existed. Presently, no such procedures are available.

The accuracy of biomass estimates can be improved by implementing the following:

- Develop regional biomass equations that predict dry weight similar to those developed for green weight.

- Group species with those for which a biomass prediction equation exists based on branching habit, such as light tolerance and crown ratio.

- Estimate bark weight by developing more widely applicable relationships of wood biomass to wood and bark biomass.

- Obtain actual stem diameters of shrub species.

- Group species with those for which there is a prediction equation for total tree height based on average tree heights, height diameter relationships, cross-sectional stem analysis, etc.

Of course, the need for prediction equations for total tree height could be alleviated by developing a wider range of equations that incorporate total tree height as a dependent variable. But there are problems even with this approach. Total tree height, especially for hardwoods, always will be difficult to measure with existing techniques. Even highly evolved mensurational equipment may depend on visually identifying exactly where the tip of the tree is.

Finally, we are still coming to grips with exactly what kind of information to publish. With new avenues for research opening up, we are faced with determining what is most valuable to researchers interested in more nontraditional forest-related issues and environmental concerns. New and more highly evolved estimation procedures may be needed for important issues like determining leaf-surface mass that relate to emissions, or for identifying the carbon sequestering potential of forests. Possibly, measuring the forest in terms of weight will be too confining in much the same way that measuring trees in terms of volume has come to be viewed as too "timber oriented." All are issues that need to be faced in the future.

Literature Cited

Alegria, J.; Scott, C.T. 1991. Generalized variance function applications in forestry. Res. Note NE-345. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 4 p.

Baldwin, V.C., Jr. 1987. Regression functions available for estimating biomass of planted southern pine. In: Wharton, E. H.; Cunia, T., eds. Estimating tree biomass regressions and their error; 1986 May 26-30; Syracuse, NY. Gen. Tech. Rep. NE-117. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 157-171.

Barrett, J.; Jastrembski, J. 1990. Regional green weight biomass equations for the Northeast. Northern Journal of Applied Forestry. 7(4): 187-189.

Brenneman, B.B.; Frederick, D.J.; Gardner, W.E.; Schoenhofen, L.H.; Marsh, P.L. 1978. Biomass of species and stands of West Virginia hardwoods. In: Central hardwoods forest conference, proceedings of the second meeting; 1978 November 14-16; West Lafayette, IN: Purdue University: 159-178.

Brown, J.K. 1976. Estimating shrub biomass from basal stem diameters. Canadian Journal of Forest Research. 6(2): 153-158.

Connally, B.J. 1981. Shrub biomass-soil relationships in Minnesota wetlands. St. Paul. MN: University of Minnesota, Department of Soil Science. 188 p. MS thesis.

Cost, N.D.; Howard, J.O.; Mead, B.; McWilliams, W.H.; Smith, W.B.; Van Hooser, D.D.; Wharton, E.H. 1990. The forest biomass resource of the United States. Gen. Tech. Rep. WO-57. Washington, DC: U.S. Department of Agriculture, Forest Service. 21 p.

Cunia, T.; Michelakackis, J.; Lee, S. 1984. Generating total tree heights by a Monte Carlo technique. In: Daniels, R. F.; Dunham, P. H.; eds. Proceedings of the 1983 southern forest biomass workshop. Fifth annual meeting of the Southern Forest Biomass Working Group; 1983 June 15-17; Charleston, SC. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 3-9.

Dennis, D.F. 1983. An analysis of Ohio's forest resources. Resour. Bull. NE-75. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 46 p.

Griffith, D.M.; DiGiovanni, D.M.; Witzel, T.L.; Wharton, E.H. 1993. Forest statistics for Ohio, 1991. Resour. Bull. NE-128. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 169 p.

Grigal, D.F.; Ohmann, L.F. 1977. Biomass equations for some shrubs from Northeastern Minnesota. Res. Note NC-226. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 3 p.

Harlow, W.H.; Harrar, E.S. 1969. Textbood of dendrology. New York: McGraw-Hill Book Company. 512 p.

Hitchcock, H.C., III; McDonnell, J.P. 1979. Biomass measurement–a synthesis of the literature. In: Forest resource inventories; 1976 June 23-26; Fort Collins, CO. Fort Collins, CO: Colorado State University: 544-595.

Hocker, H.W., Jr.; Early, D.J. 1983. Biomass and leaf area equations for northern forestry species. Res. Rep. No. 102. Durham, NH: University of New Hampshire, Agricultural Experiment Station. 27 p.

Jacobs, M.W.; Monteith, D.B. 1981. Feasibility of developing regional weight tables. Journal of Forestry. 79(10): 676-677.

Johnson, H., ed. 1973. The international book of trees. New York: Simon and Shuster, Inc.

Keays, J.L. 1971a. Complete tree utilization, an analysis of the literature–part I: unmerchantable top of bole. Inf. Rep. VP-X-69. Vancouver, BC: Canadian Forestry Service, Department of Fisheries and Forestry. 98 p.

Keays, J.L. 1971b. Complete tree utilization, an analysis of the literature–part II: foliage. Inf. Rep. VP-X-70. Vancouver, BC: Canadian Forestry Service, Department of Fisheries and Forestry. 94 p.

Keays, J.L. 1971c. Complete tree utilization, an analysis of the literature–part III: branches. Inf. Rep. VP-X-71. Vancouver, BC: Canadian Forestry Service, Department of Fisheries and Forestry. 67 p.

Keays, J.L. 1971d. Complete tree utilization, an analysis of the literature–part IV: crown and slash. Inf. Rep. VP-X-77. Vancouver, BC: Canadian Forestry Service, Department of Fisheries and Forestry. 79 p.

Keays, J.L. 1971e. Complete tree utilization, an analysis of the literature–part V: stumps, roots and stump-root system. Inf. Rep. VP-X-79. Vancouver, BC: Canadian Forestry Service, Department of Fisheries and Forestry. 62 p.

Markwardt, L.J. 1930. Comparative strength properties of woods grown in the United States. Tech. Bull. No. 158. Washington, DC: U.S. Department of Agriculture, Forest Service. 30 p.

Mead, B.R.; Yarie, J.; Herman, D. 1987. Biomass estimates for nontimber vegetation in the Tanana River Basin of interior Alaska. In: Wharton, E. H.; Cunia, T.; eds. Estimating tree biomass regressions and their error; 1986 May 26-30; Syracuse, NY. Gen. Tech. Rep. NE-117. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 149-153.

Monteith, D.B. 1979. Whole tree weight tables for New York. AFRI Res. Rep. No. 40. Syracuse, NY: State University of New York, College of Environmental Science and Forestry, Applied Forestry Research Institute. 64 p.

Peattie, D.C. 1958. A natural history of trees of eastern and central North America. New York: Bonzanza Books.

Pelz, D.R. 1987. The biomass research in Europe. In: Wharton, E. H.; Cunia, T.; eds. Estimating tree biomass regressions and their error; 1986 May 26-30; Syracuse, NY. Gen. Tech. Rep. NE-117. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 213-224.

Roussopoulos, P.J.; Loomis, R.M. 1979. Weights and dimensional properties of shrubs and small trees of the Great Lakes conifer forest. Res. Pap. NC-178. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 6 p.

Shaw, G.R. 1914. The genus Pinus. Arnold Arboretum Publ. No. 5. Boston, MA: Houghton Mifflin Co.

Smith, D.M. 1962. The practice of silviculture. New York: John Wiley and Sons. 578 p.

Smith, W.B.; Brand, G.J. 1983. Allometric biomass equations for 98 species of herbs, shrubs, and small trees. Res. Note NC-299. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 8 p.

Society of Range Management. 1974. A glossary of terms used in range management. Denver, CO: Society of Range Management.

Symonds, G.W.D.; Merwin, A.W. 1963. The shrub identification book. New York: William Morrow and Company. 379 p.

Telfer, E.S. 1969. Weight-diameter relationships for 22 woody plant species. Canadian Journal of Botany. 47: 1851-1855.

Tritton, L.M.; Hornbeck, J.W. 1982. Biomass equations for major tree species in the Northeast. Gen. Tech. Rep. NE-69. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 46 p.

U.S. Department of Agriculture, Forest Service. 1984. Tables of whole-tree weight for selected U.S. tree species. Gen. Tech. Rep. WO-42. Washington, DC: U.S. Department of Agriculture, Forest Service. 157 p.

Wartluft, J.L. 1977. Weights of small appalachian hardwood trees and components. Res. Pap. NE-366. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 4 p.

Wiant, H.V., Jr.; Sheetz, C.E.; Colaninno, A.; DeMoss, J.C.; Castaneda, F. 1977. Tables and procedures for estimating weights of some appalachian hardwoods. Bull. 659T. Morgantown, WV: West Virginia University, Agricultural and Forestry Experiment Station, College of Agriculture and Forestry. 36 p.

Yarie J.; Mead, B.R. 1988. Twig and foliar biomass equations for major plant species in the Tanana River Basin of interior Alaska. Res. Pap. PNW-401. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 20 p.

Yarie, J.; Mead, B.R. 1989. Biomass regression equations for determination of vertical structure of major understory species of southeast Alaska. Northwest Science. 63(5): 221-231.

Young, H.E. 1976. A summary and analysis of weight table studies. In: Oslo biomass studies, XVIth international congress of IUFRO; 1976 June 22; Oslo, Norway. Orono, ME: University of Maine: 251-282.

Young, H.E.; Ribe, J.H.; Wainwright, K. 1980. Weight tables for tree and shrub species in Maine. Misc. Rep. 230. Orono, ME: University of Maine, Life Sciences and Agriculture Experiment Station. 84 p.

Appendix A

Species key for green weight regression equations of northeastern tree species

Density[1] (lb/ft^3)	Tree species	Key species[2]
Evergreen Trees		
26	Atlantic white-cedar	white spruce
28	northern white-cedar	white spruce
34	black spruce	white spruce
	red spruce	white spruce
	blue spruce[3]	white spruce
	Norway spruce[3]	white spruce
35	white spruce	**key species**
36	eastern white pine	**key species**
37	eastern redcedar	red/white pine
	Douglas fir[4]	red/white pine
42	red pine	**key species**
	Scotch pine[5]	red/white pine
	Austrian pine[6]	red/white pine
	misc. evergreen trees[7]	red/white pine
45	balsam fir	**key species**
47	tamarack	balsam fir
	larch[3]	balsam fir
49	pond pine	eastern hemlock
50	jack pine	eastern hemlock
	pitch pine	eastern hemlock
	baldcypress	eastern hemlock
	eastern hemlock	**key species**
51	shortleaf pine	eastern hemlock
	Table Mountain pine[8]	eastern hemlock
	Virginia pine[8]	eastern hemlock
54	loblolly pine	eastern hemlock
Deciduous Trees		
33	pin cherry	yellow-poplar
37	striped maple	yellow-poplar
	boxelder[9]	yellow-poplar
	mountain maple[10]	yellow-poplar
	ailanthus	yellow-poplar
38	yellow-poplar	**key species**
40	balsam poplar	basswood
	cherries and plums[11]	basswood
41	northern catalpa	basswood
	Paulownia[12]	basswood
	American basswood	**key species**
	white basswood[3]	basswood
43	bigtooth aspen	quaking aspen
	quaking aspen	**key species**
44	sassafrass	quaking aspen
45	silver maple	black cherry
	blackgum	black cherry
	swamp tupelo[13]	black cherry
	aspens and cottonwoods[11]	black cherry
46	gray birch	black cherry
	pumpkin ash	black cherry

Density[1] (lb/ft^3)	Tree species	Key species[2]
46	blue ash	black cherry
	butternut	black cherry
	black cherry	**key species**
47	pawpaw[14]	black cherry
	eastern redbud[14]	black cherry
	Kentucky coffeetree[15]	black cherry
48	sugarberry	white ash
	white ash	**key species**
	ashes[11]	white ash
49	yellow buckeye	white ash
	Ohio buckeye[3]	white ash
	buckeyes\horsechestnuts[11]	white ash
	green ash	white ash
	cucumbertree	white ash
	sweetbay[3]	white ash
	magnolia[3]	white ash
	eastern cottonwood	white ash
	swamp cottonwood[3]	white ash
50	red maple	**key species**
	paper birch	red/sugar maple
	river birch[16]	red/sugar maple
	hackberry	red/sugar maple
	sweetgum	red/sugar maple
	black willow	red/sugar maple
	willows[11]	red/sugar maple
51	maples[11]	red/sugar maple
52	sycamore	American beech
53	American hornbeam	American beech
	black ash	American beech
	sourwood	American beech
54	black maple	American beech
	American beech	**key species**
	winged elm[17]	American beech
	American elm	American beech
	rock elm	American beech
	birches[11]	American beech
	elms[11]	American beech
55	American chestnut	yellow birch
	apple	yellow birch
	misc. deciduous trees[11]	yellow birch
56	sugar maple	yellow birch
	water tupelo	yellow birch
	slippery elm	yellow birch
57	yellow birch	**key species**
	sweet birch	yellow birch
	American holly	yellow birch
58	black locust	yellow birch
	yellowwood[18]	yellow birch
	black walnut	yellow birch

Density[1] (lb/ft^3)	Tree species	Key species[2]
60	nutmeg hickory	oaks
	eastern hophornbeam	oaks
	white mulberry[19]	oaks
	red mulberry[19]	oaks
	mulberries[19]	oaks
	chokecherry[20]	oaks
60	American mountain-ash[21]	oaks
	European mountain-ash[21]	oaks
61	serviceberry	oaks
	pecan	oaks
	honeylocust	oaks
	chestnut oak	**key species**
62	Osage-orange	oaks
	white oak	**key species**
	scarlet oak	**key species**
	southern red oak	oaks
	bur oak	oaks
63	overcup oak[22]	oaks
	chinkapin oak[22]	oaks
	water oak	oaks
	pin oak	oaks
	northern red oak	**key species**

Density[1] (lb/ft^3)	Tree species	Key species[2]
63	post oak	oaks
	black oak	**key species**
	bitternut hickory	**key species**
	shellbark hickory[23]	**key species**
	hawthorn	hickories
	persimmon	hickories
	hickories[11,24]	**key species**
64	pignut hickory	**key species**
	shagbark hickory	**key species**
	mockernut hickory	**key species**
	flowering dogwood	hickories
	northern pin oak[22]	oaks
	bear oak[25]	oaks
	shingle oak[25]	oaks
	blackjack oak[25]	oaks
	Shumard oak[25]	oaks
65	laurel oak	oaks
	swamp chestnut oak	oaks
67	willow oak	oaks
68	water hickory	**key species**
	cherrybark oak	oaks
69	swamp white oak	oaks

[1]Where no density was available, averages have been assigned. Evergreen trees averaged 42 pounds per cubic foot, light deciduous trees averaged 47 pounds per cubic foot, and heavy deciduous trees averaged 60 pounds per cubic foot, green-weight basis.

[2]Key species are those for which there is a regression equation . The coefficients for key species were used to approximate other species with similar characteristics, primarily wood density.

[3]No green-weight density is available, but densities were available from within the same genus.

[4]Average of coast type, inland empire type, and Rocky Mountain type (Markwardt 1930).

[5]Shaw (1914) places Scotch pine in the subgenus Diploxylon, subsection Pinaster, and group Lariciones. Red pine also is placed in this taxonomic classification.

[6]Superficially, Austrian pine is similar to red pine (Harlow and Harrar 1969).

[7]No green-weight density is available. The average density for evergreen trees–42 pounds per cubic foot–has been used (refer to footnote 1).

[8]Both Table Mountain pine and Virginia pine are small to medium-sized trees. In the Northeast, Table Mountain pine is found sparingly on dry, often rocky slopes (Harlow and Harrar 1969). Both species are similar to shortleaf pine in superficial characteristics and range.

[9]Boxelder, in terms of dry weight, most closely approximates silver maple and striped maple. Boxelder averages 27 pounds per cubic foot; the latter two maples average 33 pounds per cubic foot (Peattie 1958). Lacking a justifiable green-weight density, boxelder is placed with striped maple, the least dense maple in terms of green weight.

[10]Mountain maple is similar to striped maple, both superficially and by density; both species average 33 pounds per cubic foot, dry-weight basis (Peattie 1958).

[11]Average pounds per cubic foot are used for those species where only the genus is known. Cherries and plums average 40; aspens and cottonwoods average 45; ashes average 48; willows average 50; maples average 51; birches and elms average 54; hickories average 63; and miscellaneous or unknown evergreen trees and deciduous trees average, respectively, 42 and 55 pounds per cubic foot, green-weight basis. In the case of buckeyes and horsechestnuts, only one density is available: 49 pounds per cubic foot for yellow buckeye (Markwardt 1930).

[12]Paulownia is similar to catalpa in many ways, even though they are in different botanical families, Bignoniaceae and Scrophulariaceae respectively (Johnson 1973).

[13]Harlow and Harrar (1969) consider swamp tupelo a variety of blackgum, *Nyssa sylvatica* var. *biflora*.

[14]No green-weight density is available. The average density for light deciduous trees–47 pounds per cubic foot–has been used (refer to footnote 1).

[15]Kentucky coffeetree is botanically in the same subfamily as honeylocust and eastern redbud, Caesalpiniodeae (Harlow and Harrar 1969). In terms of wood density, it is more likely related to eastern redbud; the Forest Service identifies Kentucky coffeetree as a soft hardwood.

[16]The desity of river birch, 40 pounds per cubic foot, most closely resembles paper birch, 39 pounds per cubic foot, dry-weight basis (Peattie 1958).

[17]Harlow and Harrar (1969) indicate that winged elm has been harvested as a substitute for rock elm.

[18]Yellowwood is of the subfamily Papilionoideae, of the Leguminosea family (Harlow and Harrar 1969). The only other northeastern species in this taxonomic classification is black locust.

[19]Mulberry is similar to Osage-orange; both are in the family Moraceae. While the wood of mulberry probably is not as heavy as that of Osage-orange, it is considered to have wood of medium weight (Peattie 1958). This, coupled with the fact that the Forest Service lists red mulberry as a hard deciduous tree, indicates that both red and white mulberry may be at or slightly over the limit for heavy deciduous trees. The average density for a heavy deciduous tree–60 pounds per cubic foot–has been used (refer to footnote 1).

[20]Peattie (1958) indicates that the wood of chokecherry is heavy and hard. The average density for a heavy deciduous trees–60 pounds per cubic foot–has been used (refer to footnote 1).

[21]The wood of the rowan-tree, as these two species have been called, generally is characterized as medium-light (Peattie 1958). However, its dry-weight density of 34 pounds per cubic foot indicates that it may be a heavy deciduous tree; medium-light deciduous trees such as eastern redbud and mulberry are classed as heavy deciduous trees. The average density for a heavy deciduous trees–60 pounds per cubic foot–has been used (refer to footnote 1).

[22]This species falls in the subgenera Leucobalanus, the white oaks (Harlow and Harrar 1969), which average 63 pounds per cubic foot, green-weight basis (Markwardt 1930).

[23]Shellbark hickory falls into the subgenera Eucarya, the true hickories (Harlow and Harrar 1969), which average 63 pounds per cubic foot, green-weight basis (Markwardt 1930).

[24]Oak or hickory could be used to predict the weight of trees whose densities are 63 pound per cubic foot or greater. Hickory was selected to predict the weight of trees in its own genus and other heavy deciduous trees; oak was selected to predict the weight of all oaks greater than 63 pounds per cubic foot.

[25]This species falls in the subgenera Erythrobalanus, the red or black oaks (Harlow and Harrar 1969), which average 64 pounds per cubic foot, green-weight basis (Markwardt 1930).

Appendix B

Species key for dry weight regression equations of northeastern tree species

Density[1] (lb/ft^3)	Tree species	Key species[2]
Evergreen Trees		
22	northern white-cedar	**key species**
23	Atlantic white-cedar	n. white cedar
25	eastern white pine	**key species**
26	balsam fir	**key species**
28	white spruce	red spruce
	black spruce	red spruce
	red spruce	**key species**
	blue spruce[3]	red spruce
	Norway spruce[3]	red spruce
	eastern hemlock	**key species**
30	jack pine	eastern hemlock
	Table Mountain pine[4]	eastern hemlock
31	misc. evergreen trees[5]	eastern hemlock
33	baldcypress	red pine
32	eastern redcedar	red pine
	Virginia pine[4]	red pine
	Douglas fir[6]	red pine
34	red pine	**key species**
	pitch pine	red pine
	Scotch pine[7]	red pine
	Austrian pine[8]	red pine
37	tamarack	larch
	larch[3]	**key species**
38	shortleaf pine	larch
	pond pine	larch
	loblolly pine	larch
Deciduous Trees		
23	balsam poplar	quaking aspen
24	ailanthus	quaking aspen
25	yellow buckeye	quaking aspen
	pawpaw[9]	quaking aspen
	swamp cottonwood[9]	quaking aspen
	buckeyes/horsechestnuts[10]	quaking aspen
26	black willow	quaking aspen
	American basswood	quaking aspen
	white basswood[11]	quaking aspen
	willows	quaking aspen
	aspens and cottonwoods	quaking aspen
27	boxelder[9]	quaking aspen
	butternut	quaking aspen
	bigtooth aspen	quaking aspen
	quaking aspen	**key species**
28	Ohio buckeye[9]	yellow-poplar
	yellow-poplar	**key species**
	eastern cottonwood	yellow-poplar
	pin cherry	yellow-poplar
29	northern catalpa	yellow-poplar
	Paulownia[12]	yellow-poplar

Density[1] (lb/ft^3)	Tree species	Key species[2]
30	American chestnut	yellow-poplar
32	striped maple	black cherry
	sassafrass	black cherry
	cherries and plums[10]	black cherry
33	silver maple	black cherry
	mountain maple[9]	black cherry
34	black ash	black cherry
	sweetgum	black cherry
	cucumbertree	black cherry
	sweetbay[11]	black cherry
	American mountain-ash[9]	black cherry
	European mountain-ash[11]	black cherry
35	gray birch	black cherry
	water tupelo	black cherry
	blackgum	black cherry
	swamp tupelo[13]	black cherry
	sycamore	black cherry
	black cherry	**key species**
36	sugarberry	red maple
	pumpkin ash	red maple
	American elm	red maple
37	hackberry	red maple
	red mulberry[9]	red maple
	white mulberry[11]	red maple
	slippery elm	red maple
38	red maple	**key species**
	sourwood	red maple
	ashes	red maple
39	paper birch	red maple
	eastern redbud[9]	red maple
	yellowwood[9]	American beech
	black walnut	red maple
	birches	red maple
	elms[10]	red maple
40	black maple	red maple
	river birch[9]	red maple
	green ash	red maple
	blue ash	red maple
	American holly	red maple
	maples[10]	red maple
41	Kentucky coffeetree[9]	white ash
	southern red oak	white ash
42	nutmeg hickory	white ash
	white ash	**key species**
	hardwoods[10]	white ash
43	yellow birch	**key species**
	water hickory	black oak
	black oak	**key species**
44	sugar maple	**key species**
	honeylocust	sugar maple

Density[1] (lb/ft^3)	Tree species	Key species[2]
44	northern pin oak	northern red oak
	bear oak[14]	northern red oak
	laurel oak	norrthern red oak
	water oak	northern red oak
	pin oak	northern red oak
	northern red oak	**key species**
	Shumard oak[14]	northern red oak
	rock elm	northern red oak
45	American beech	**key species**
	bur oak	American beech
46	sweet birch	chestnut oak
	bitternut hickory	chestnut oak
	blackjack oak[9]	chestnut oak
	chestnut oak	**key species**
47	pecan	scarlet oak
	apple	scarlet oak
	scarlet oak	**key species**
	shingle oak[9]	scarlet oak
	swamp chestnut oak	scarlet oak
	post oak	scarlet oak
	hawthorn	white oak

Density[1] (lb/ft^3)	Tree species	Key species[2]
47	water hickory	scarlet oak
	winged elm[9]	scarlet oak
48	American hornbeam	white oak
48	black locust	white oak
	Osage-orange[15]	white oak
	chokecherry[15]	white oak
	white oak	**key species**
	cherrybark oak	white oak
49	willow oak	white oak
50	eastern hophornbeam	hickory
	shellbark hickory[9]	hickory
	swamp white oak	hickory
	hickories[10]	hickory
51	shagbark hickory	hickory
	mockernut hickory	hickory
	flowering dogwood	hickory
	overcup oak[9]	hickory
52	serviceberry	hickory
54	persimmon	hickory
	chinkapin oak[9]	hickory
63	pignut hickory	hickory

[1]Where no density was available, averages have been assigned. Evergreen trees and light deciduous trees averaged 31 pounds per cubic foot, and heavy deciduous trees averaged 48 pounds per cubic foot, dry-weight basis.

[2]Key species are those for which there is a regression equation. The coefficients for key species were used to approximate other species with similar characteristics, primarily wood density.

[3]No dry-weight density is available, but densities were available from within the same genus.

[4]Dry-weight ratio from Peattie (1958).

[5]No dry-weight density is available. The average density for evergreen trees–31 pounds per cubic foot–has been used (refer to footnote 1).

[6]Average of coast type, inland empire type, and Rocky Mountain type (Markwardt 1930).

[7]Shaw (1914) places Scotch pine in the subgenus Diploxylon, subsection Pinaster, and group Lariciones. Red pine also is in this taxonomic classification.

[8]Superficially, Austrian pine is similar to red pine (Harlow and Harrar 1969).

[9]Dry-weight ratio from Peattie (1958).

[10]Averages are used for those species where only the genus is known. Cherries and plums average 32, elms average 39, maples average 40, deciduous trees average 42, and hickories average 50 pounds per cubic foot, dry-weight basis. In the case of buckeyes and horsechestnuts, only one density is available: 25 pounds per cubic foot for yellow buckeye (Markwardt 1930).

[11]No dry-weight density is available, but densities were available from within the same genus.

[12]Paulownia is similar to catalpa in many ways, even though they are in different botanical families, Bignoniaceae and Scrophulariaceae, respectively (Johnson 1973).

[13]Harlow and Harrar (1969) consider swamp tupelo a variety of blackgum, classifying it as *Nyssa sylvatica* var. *biflora.*

[14]This species falls into the subgenera Erythrobalanus, the red or black oaks (Harlow and Harrar 1969), which average 44 pounds per cubic foot, dry-weight basis (Markwardt 1930).

[15]No dry-weight density is available. The average density for heavy deciduous trees–48 pounds per cubic foot–has been used (refer to footnote 1).

Appendix C

Species key for dry weight regression equations of northeastern shrub species

Shrub species	Key species[1]
common juniper	**key species**
Canada yew	common juniper[2]
alder	**key species**
Hercules club	European red raspberry[2]
bog rosemary	Labrador tea[3]
chokeberry	alder-leaved buckthorn[3]
azalea	rhododendron[3]
barberry	**key species**
New Jersey tea	**key species**
leatherleaf	**key species**
fringetree	sheep laurel[3]
sweetfern	**key species**
alternate-leaved dogwood	red-osier dogwood
silky dogwood	red-osier dogwood
round-leaved dogwood	**key species**
gray-stemmed dogwood	round-leaved dogwood
red-osier dogwood	**key species**
American hazelnut	bleaked hazelnut
bleaked hazelnut	**key species**
leatherwood	red-osier dogwood[3]
autumn olive	mountain-holly[3]
huckleberry	black huckleberry[4]
witch-hazel	**key species**
large-leaf holly	winterberry holly
winterberry holly	**key species**
sheep laurel	**key species**
mountain laurel	sheep laurel
Labrador tea	**key species**
common spicebush	red-osier dogwood[3]
honeysuckle	American-fly honeysuckle[4]
Allegheny menziesia	rust menziesia[4]
bayberry	**key species**
mountain-holly	**key species**
ninebark	mallow ninebark[4]
buckthorn	alder-leaved buckthorn[4]
rhododendron	rhodora[4]
winged sumac	red-osier dogwood[2]
smooth sumac	red-osier dogwood[2]
staghorn sumac	red-osier dogwood[2]
poison sumac	red-osier dogwood[2]
current, gooseberry	**key species**
rose	key species
brier, bramble, raspberry	European red raspberry[4]
American elderberry	red-osier dogwood[2]
red-berried elderberry	red-osier dogwood[2]
buffalo-berry, soapberry	**key species**
spirea	**key species**
snowberry	**key species**
sweetleaf	mountain-holly[3]
American bladdernut	red-osier dogwood[3]
blueberry	**key species**
viburnum	American wayfaring tree[4]
maple-leaved viburnum	American wayfaring tree[4]
hobblebush viburnum	American wayfaring tree[4]
wild raisin	American wayfaring tree[4]
arrowwood	American wayfaring tree[4]
nannyberry	American wayfaring tree[4]
blackhaw	American wayfaring tree[4]
highbush cranberry	American wayfaring tree[4]
common prickly-ash	red-osier dogwood[2]
unknown deciduous shrub	European red raspberry[5]
unknown evergreen shrub	sheep laurel[6]

[1]Key species are those for which there is a regression equation. The coefficients for key species were used to approximate other species with similar characteristics. Unless otherwise noted, key species were from within the same genus.

[2]Based on Symonds and Merwin (1963). Where an equation did not exist, common juniper, *Juniperus communis*, was used for evergreen, needled species; sheep laurel, *Kalmia augustifolia*, was used for evergreen, broad-leaved species; and red-osier dogwood, *Cornus stolonifera*, was used for high deciduous shrubs.

[3]Based on personal communication with Robert T. Brooks, USDA Forest Service, Northeastern Forest Experiment Station, Forest Inventory and Analysis, Amherst, MA, 30 May 1991.

[4]Key species that are not northeastern species, and so do not appear in Appendix E, northeastern trees and shrubs. They are: black huckleberry, *Gaylussacia baccata*; American-fly honeysuckle, *Lonicera canadensis*; rust menziesia, *Menziesia ferruginea*; mallow ninebark, *Physocarpus malvaceus*; alder-leaved buckthorn, *Rhamnus alnifolia*; rhodora, *Rhododendron canadense*; European red raspberry, *Rubus idaeus*; American wayfaring tree, *Viburnum latanoides*.

[5]Unknown deciduous shrubs were assumed to be low shrubs, probably brambles or briers.

[6]Unknown evergreen shrubs were assumed to be broad leaved, probably closest in form and habitat to laurel.

Appendix D

Species key for total tree height regression equations, northeastern tree species

Species	Height (feet)	Bole and crown characteristics[1]	Key species[2]
Evergreen Trees			
balsam fir	40-60	moderately tapering bole–dense narrow pyramidal crown	**key species**
Atlantic white-cedar	80-85	long, cylindrical, clear bole–small, narrow, conical crown	balsam fir
eastern redcedar	40-50	tapering bole–dense, narrow, pyrimidal crown	balsam fir
larch	140-180	long, clear bole–short, open, pyramidal crown	red pine
tamarack	40-80	long, clear, cylindrical bole–open, pyramidal crown	red pine
Norway spruce	tall	–[3]	white spruce
white spruce	60-70	–[3]	**key species**
black spruce	30-40	long, straight, tapering bole–irregular, cylindrical crown	white spruce
blue spruce	100-120	–[3]	white spruce
red spruce	60-70	long, cylindrical bole–pagoda-shaped crown	white spruce
jack pine	70-80	irregular, rounded crown	red pine
shortleaf pine	80-100	well-formed, clear bole-small, narrow, pyramidal crown	red pine
Table Mountain pine	medium	–[3]	red pine
red pine	50-80	well-formed, long, cylindrical bole-symmetric, oval crown	**key species**
pitch pine	50-60	mostly tall, columnar bole-open, small crown	red pine
pond pine	medium	southern variety of pitch pine	red pine
eastern white pine	80-100	tall, clear, cylindrical bole-plume-like crown	red pine
Scotch pine	–[3]	–[3]	red pine
loblolly pine	90-110	long, cylindrical bole-open, yet dense crown	red pine
Virginia pine	40	small bole-unkempt crown	red pine
Austrian pine	50-80	similar to red pine	red pine
Douglas fir	180-250	long, cylindrical bole-rounded or irregular, flat-topped crown	white spruce
baldcypress	100-120	tapering bole-irregular, flattened crown	white spruce
northern white-cedar	40-50	tapering bole-irregular, oblong crown	balsam fir
eastern hemlock	60-70	tapering bole-pyramidal crown; branches may touch ground	balsam fir
Deciduous Trees			
boxelder	75	irregular bole-bushy, spreading crown	red maple
black maple	60-80	similar to sugar maple	sugar maple
striped maple	small	shrub-like	red maple
red maple	50-70	long bole–irregular crown	**key species**
silver maple	60-80	short bole, dividing low into branches	red maple
sugar maple	60-80	straight, full bole	**key species**
mountain maple	small	shrub-like	red maple
Ohio buckeye	60-90	–[3]	white ash
yellow buckeye	60-90	–[3]	white ash
ailanthus	–[3]	–[3]	red maple
serviceberry	small	shrub-like	red maple
pawpaw	–[3]	–[3]	red maple
yellow birch	60-70	long, well-formed bole–round, irregular crown	**key species**
sweet birch	50-60	long, clear bole	yellow birch
river birch	70-80	dividing bole, several branches	yellow birch
paper birch	50-70	long, clear bole–open, irregular, pyramidal crown	yellow birch
gray birch	20-30	poorly shaped bole, limby–open, irregular, pyramidal crown	red maple
American hornbeam	small	poorly formed, twisted bole	red maple
water hickory	110-140	similar to pecan	yellow-poplar
bitternut hickory	50-60	–[3]	yellow-poplar

Species	Height (feet)	Bole and crown characteristics[1]	Key species[2]
pignut hickory	50-60	–[3]	black cherry
pecan	110-140	–[3]	yellow-poplar
shellbark hickory	70-80	similar to shagbark hickory	basswood
nutmeg hickory	80-100	–[3]	basswood
shagbark hickory	70-80	straight, cylindrical bole–oblong crown	basswood
mockernut hickory	40-60	–[3]	black cherry
American chestnut	small	blight-affected	red maple
Northern catalpa	120	well-formed bole (may be crooked)	yellow-poplar
sugarberry	60-80	–[3]	sugar maple
hackberry	30-40	–[3]	yellow birch
eastern redbud	small	–[3]	red maple
yellowwood	–[3]	–[3]	red maple
flowering dogwood	40	short bole, branchy–low, dense crown	red maple
hawthorn	small	shrub-like	red maple
persimmon	30-50	short bole–round-topped crown	red maple
American beech	70-80	straight, clear, massive bole–spreading crown	key species
white ash	70-80	long, straight, cylindrical bole–crown open	key species
black ash	40-50	poorly formed bole–small, open crown	yellow birch
green ash	30-50	short, poorly formed bole–broad, irregular crown	yellow birch
pumpkin ash	–[3]	–[3]	yellow birch
blue ash	medium	–[3]	yellow birch
honeylocust	70-80	short bole–open, spreading crown	red maple
Kentucky coffeetree	medium	–[3]	red maple
American holly	40-50	straight, short bole	red maple
butternut	40-60	short bole, stout limbs–broad, open crown	beech
black walnut	70-90	tall, well-formed bole–small, open crown	basswood
sweetgum	80-120	long, straight bole–small, oblong or pyramidal crown	basswood
yellow-poplar	100-120	tall, clear, arrow-straight bole–small, open, oblong crown	**key species**
Osage-orange	small	shrub-like	red maple
cucumbertree	80-90	straight, clear bole–pyramidal crown	basswood
sweetbay	60-70	similar to cucumbertree	basswood
apple	–[3]	–[3]	red maple
white mulberry	small	shrub-like	red maple
red mulberry	small	shrub-like	red maple
water tupelo	80-90	long, clear bole–crown narrow and open	basswood
blackgum	50-60	–[3]	black cherry
swamp tupelo	50-60	similar to blackgum	black cherry
eastern hophornbeam	small	similar to hornbeam	red maple
sourwood	small	–[3]	red maple
Paulownia	–[3]	–[3]	red maple
Sycamore	80-100	open, spreading crown	beech
balsam poplar	60-80	long, cylindrical bole–narrow, pyramidal crown	quaking aspen
eastern cottonwood	80-100	ong, cylindrical bole–somewhat small crown	quaking aspen
bigtooth aspen	60-70	similar to quaking aspen	quaking aspen
swamp cottonwood	medium	similar to other cottonwoods	quaking aspen
quaking aspen	50-60	long, clear bole–small, rounded crown	**key species**
pin cherry	small	shrub-like	red maple
black cherry	50-60	long, straight, clear, cylindrical bole–narrow, oblong crown	**key species**
chokecherry	small	shrub-like	red maple
white oak	80-100	short, stocky bole–wide-spreading crown	**key species**
swamp white oak	60-70	poorly pruned bole–irregular crown	scarlet oak
scarlet oak	70-80	–[3]	**key species**
northern pin oak	70-80	similar to pin oak	white oak
southern pin oak	60-80	similar to southern red oak	northern red oak

Species	Height (feet)	Bole and crown characteristics[1]	Key species[2]
cherrybark oak	100-130	clear bole	northern red oak
bear oak	–[3]	–[3]	chestnut oak
shingle oak	50-60	–[3]	chestnut oak
laurel oak	60-70	–[3]	scarlet oak
overcup oak	70-80	poorly-formed, short, twisted bole–large, open crown	white oak
bur oak	70-80	massive bole, stout branches–broad crown	white oak
blackjack oak	small	poorly formed bole	chestnut oak
swamp chestnut oak	60-80	well-formed, straight, massive bole–narrow crown	northern red oak
chinkapin oak	60-80	–[3]	northern red oak
water oak	60-70	tall, slender bole–symmetrical, rounded crown	northern red oak
pin oak	70-80	tough-studded-branchlet bole–broad, pyramid crown	white oak
willow oak	80-100	full rounded crown, slender lower branches	white oak
chestnut oak	50-60	–[3]	**key species**
northern red oak	60-80	tall, straight, columnar bole–small rounded bole	**key species**
Shumard oak	100-125	Long, clear, symmetrical bole–open, wide-spreading crown	scarlet oak
post oak	40-50	gnarled, twisted bole–often shrubby crown	chestnut oak
black oak	50-60	tapering, limby bole–irregular, rounded crown	black oak
black locust	40-60	poorly formed bole–spreading crown	red maple
black willow	30-60	broad, irregular crown	red maple
sassafrass	60-80	–[3]	red maple
American mountain-ash	small	shrub-like	red maple
Europeon mountain-ash	small	shrub-like	red maple
American basswood	70-80	long, cylindrical bole	**key species**
white basswood	60-80	similar to American basswood	basswood
winged elm	small	–[3]	red maple
American elm	80-100	columnar trunk, branching at 50-60 feet–small, arching crown	yellow-poplar
slippery elm	60-70	great clear bole	yellow-poplar
rock elm	60-80	tall, straight, unbranched bole–narrow, oblong crown	yellow-poplar
unknown species			red maple

[1]Bole and crown characteristics from Harlow and Harrar (1969).

[2]Key species are those for which there is a regression equation. The coefficients for key species are then used to approximate other species with similar characteristics. Refer to the appropriate table of regression coefficients.

[3]Information is not available.

Appendix E

Northeastern tree and shrub species

Common name	Genus and species
Evergreen Trees	
fir	*Abies sp.*
balsam fir	*A. balsamea*
cedar	*Chamaecyparis sp.*
Atlantic white-cedar	*C. thyoides*
eastern redcedar	*Juniperus virginiana*
larch	*Larix sp.*
tamarack	*L. laricina*
Norway spruce	*Picea abies*
white spruce	*P. glauca*
black spruce	*P. mariana*
blue spruce	*P. pungens*
red spruce	*P. rubens*
jack pine	*Pinus banksiana*
shortleaf pine	*P. echinata*
Table Mountain pine	*P. pungens*
red pine	*P. resinosa*
pitch pine	*P. rigida*
pond pine	*P. serotina*
eastern white pine	*P. strobus*
Scotch pine	*P. sylvestris*
loblolly pine	*P. taeda*
Virginia pine	*P. virginiana*
Austrian pine	*P. nigra*
Douglas fir	*Pseudotsuga menziesii*
baldcypress	*Taxodium distichum*
northern white-cedar	*Thuja occidentalis*
eastern hemlock	*Tsuga canadensis*
Deciduous Trees	
maple	*Acer sp.*
boxelder	*A. negundo*
black maple	*A. nigrum*
striped maple	*A. pensylvanicum*
red maple	*A. rubrum*
silver maple	*A. saccharinum*
sugar maple	*A. saccharum*
mountain maple	*A. spicatum*
buckeye, horsechestnut	*Aesculus sp.*
Ohio buckeye	*A. glabra*
yellow buckeye	*A. octandra*
ailanthus	*Ailanthus altissima*
serviceberry	*Amelamchier sp.*
pawpaw	*Asimina triloba*
birches	*Betula sp.*
yellow birch	*B. alleghaniensis*
sweet birch	*B. lenta*
river birch	*B. nigra*
paper birch	*B. papyrifera*
gray birch	*B. populifolia*
American hornbeam	*Carpinus caroliniana*

Common name	Genus and species
hickory	*Carya sp.*
water hickory	*Carya aquatica*
bitternut hickory	*C. cordiformis*
pignut hickory	*C. glabra*
pecan	*C. illinoensis*
shellbark hickory	*C. laciniosa*
shagbark hickory	*C. ovata*
mockernut hickory	*C. tomentosa*
American chestnut	*Castanea dentata*
catalpa	*Catalpa sp.*
Northern catalpa	*C. speciosa*
sugarberry	*Celtis laevigata*
hackberry	*C. occidentalis*
eastern redbud	*Cercis canadensis*
yellowwood	*Cladrastis lutea*
flowering dogwood	*Cornus florida*
hawthorn	*Crataegus sp.*
persimmon	*Diospyros virginiana*
American beech	*Fagus grandifolia*
ash	*Fraxinus sp.*
white ash	*F. americana*
black ash	*F. nigra*
green ash	*F. pennsylvanica*
pumpkin ash	*F. profunda*
blue ash	*F. quadrangulata*
honeylocust	*Gleditsia triacanthos*
Kentucky coffeetree	*Gymnocladus dioicus*
American holly	*Ilex opaca*
butternut	*Juglans cinerea*
black walnut	*J. nigra*
sweetgum	*Liquidambar styraciflua*
yellow-poplar	*Liriodendron tulipifera*
Osage-orange	*Maclura pomifera*
magnolia	*Magnolia sp.*
cucumbertree	*M. acuminata*
sweetbay	*M. virginiana*
apple	*Malus sp.*
mulberry	*Morus sp.*
white mulberry	*M. alba*
red mulberry	*M. rubra*
tupelo	*Nyssa sp.*
water tupelo	*N. aquatica*
blackgum	*N. sylvatica*
swamp tupelo	*N. biflora*
eastern hophornbeam	*Ostrya virginiana*
sourwood	*Oxydendrum arboreum*
Paulownia	*Paulownia tomentosa*
American sycamore	*Platanus occidentalis*
poplar, cottonwood	*Populus sp.*
balsam poplar	*P. balsamifera*
eastern cottonwood	*P. deltoides*
bigtooth aspen	*P. grandidentata*

Common name	Genus and species
swamp cottonwood	*Populus heterophylla*
quaking aspen	*P. tremuloides*
cherry, plum	*Prunus sp.*
pin cherry	*P. pensylvanica*
black cherry	*P. serotina*
chokecherry	*P. virginiana*
oak	*Quercus sp.*
white oak	*Q. alba*
swamp white oak	*Q. bicolor*
scarlet oak	*Q. coccinea*
northern pin oak	*Q. ellipsoidalis*
southern pin oak	*Q. falcata var. falcata*
cherrybark oak	*Q. falcata var. pagodaefolia*
bear oak	*Q. ilicifolia*
shingle oak	*Q. imbricaria*
laurel oak	*Q. laurifolia*
overcup oak	*Q. lyrata*
bur oak	*Q. macrocarpa*
blackjack oak	*Q. marilandica*
swamp chestnut oak	*Q. michauxii*
chinkapin oak	*Q. muehlenbergii*
water oak	*Q. nigra*
pin oak	*Q. palustris*
willow oak	*Q. phellos*
chestnut oak	*Q. prinus*
northern red oak	*Q. rubra*
Shumard oak	*Q. shumardii*
post oak	*Q. stellata*
black oak	*Q. velutina*
black locust	*Robinia psuedoacacia*
willow	*Salix sp.*
black willow	*S. nigra*
sassafrass	*Sassafras albidum*
American mountain-ash	*Sorbus americana*
Europeon mountain-ash	*S. aucuparia*
basswood	*Tilia sp.*
American basswood	*T. americana*
white basswood	*T. heterophylla*
elm	*Ulmus sp.*
winged elm	*U. alata*
American elm	*U. americana*
slippery elm	*U. rubra*
rock elm	*U. thomasii*

Evergreen Shrubs

Common name	Genus and species
common juniper	*Juniperus communis*
Canada yew	*Taxus canadensis*
bog rosemary	*Andromeda glaucophylla*
sheep laurel	*Kalmia augustifolia*
mountain laurel	*K. latifolia*
Labrador tea	*Ledum groenlandicum*
rhododendron	*Rhododendron sp.*
sweetleaf	*Symplocos tinctoria*

Deciduous Shrubs

Common name	Genus and species
alder	*Alnus sp.*
Hercules club	*Aralia spinosa*
chokeberry	*Aronia sp.*
azalea	*Azalea sp.*
barberry	*Berberis sp.*
New Jersey tea	*Ceanothus americanus*
leatherleaf	*Chamaedaphne calyculata*
fringetree	*Chionanthus virginicus*
sweetfern	*Comptonia peregrina*
alternate-leaved dogwood	*Cornus alternifolia*
silky dogwood	*C. amomum (obliqua)*
round-leaved dogwood	*C. rugosa (circinata)*
gray-stemmed dogwood	*C. racemosa (paniculata)*
red-osier dogwood	*C. stolonifera*
American hazelnut	*Corylus americana*
bleaked hazeknut	*C. cornuta*
leatherwood	*Dirca palustris*
autumn olive	*Elaeagnus augustifolia*
huckleberry	*Gaylussacia sp.*
witch-hazel	*Hamamelis virginiana*
large-leaf holly	*Ilex montana (monticola)*
winterberry holly	*I. verticillata*
common spicebush	*Lindera benzoin*
honeysuckle	*Lonicera sp.*
Allegheny menziesia	*Menziesia pilosa*
bayberry	*Myrica pensylvanica*
mountain-holly	*Nemopanthus mucronatus*
ninebark	*Physocarpus opulifolius*
buckthorn	*Rhamnus sp.*
winged sumac	*Rhus copallina*
smooth sumac	*R. glabra*
staghorn sumac	*R. typhina*
poison sumac	*R. vernix*
current, gooseberry	*Ribes sp.*
rose	*Rosa sp.*
brier, bramble, raspberry	*Rubus sp.*
American elderberry	*Sambucus canadensis*
red-berried elderberry	*S. racemosa*
buffalo-berry, soapberry	*Shepherdia canadensis*
spirea	*Spirea sp.*
snowberry	*Symphoricarpos albus*
American bladdernut	*Staphylea trifolia*
blueberry	*Vaccinium sp.*
viburnum	*Viburnum sp.*
maple-leaved viburnum	*V. acerifolium*
hobblebush viburnum	*V. alnifolium*
wild raisin	*V. cassinoides*
arrowwood	*V. dentatum*
nannyberry	*V. lentago*
blackhaw	*V. prunifolium*
highbush cranberry	*V. trilobum*
common prickly-ash	*Zanthoxylum americanum*

Appendix F

Definitions

The following definitions are based on the USDA Forest Service's "Forest Survey Handbook", except for those dealing with shrubs, which are based on definitions from the Society of Range Management (1974).

Board foot–A unit of lumber measurement 1 foot long, 1 foot wide, and 1 inch thick, or its equivalent.

Biomass–The quantity of material in a living organism, measured in weight.

Branches–All wood and bark outside of the minimum top diameter of the merchantable stem. Includes the unmerchantable stem, branches, and twigs; excludes foliage.

Cull tree–A rough cull tree or rotten cull tree.

Dead tree–A tree whose cambium is no longer living, ordinarily indicated by permanent loss of all foliage. The tree may be standing, fallen, windthrown, knocked down, or broken off.

Deciduous–Dicotyledonous trees and shrubs, having broad leaves that drop seasonally, though some are persistent. Deciduous trees are commonly called hardwoods even though some have soft wood.

Density–Weight per unit volume, usually expressed in lb/ft^3 or gm/cm^3. Basic wood density is based on oven-dry weight and green volume.

Diameter at breast height (d.b.h.)–The diameter taken outside the bark of standing trees measured at 4½ feet above the ground.

Diameter outside bark (d.o.b.)–The diameter taken outside the bark at some specified point on the main stem of a standing or down tree.

Dry weight–A unit of measure, when applied to trees, is the oven-dry weight of wood and bark, expressed in pounds or tons.

Evergreen–Trees and shrubs having needles or scale-like leaves, usually cone-bearing. Evergreen trees are commonly called softwoods even though some have hard wood.

Foliage–The leaves and fruits in trees and shrubs.

Forest biomass–The weight of wood, bark, and foliage in all living woody plants. Includes the biomass of growing stock, above and below ground biomass of timber, and the aboveground biomass of salvable dead trees, seedlings, saplings, and shrubs. Does not include the biomass of grasses, forbs, or other similar herbaceous plants.

Forest land–Land areas 1 acre in size at least 10-percent stocked with trees of any size, or that formerly had such tree cover and are not currently developed for a nonforest use.

Geographic unit–A county or a group of counties within a state large enough to provide an adequate sample base and have common physiographic features.

Green weight–A unit of measure, when applied to trees and shrubs, is the weight of wood and bark while they are alive, freshly cut, or still containing most of the moisture present at the time of cutting. Expressed in pounds or tons.

Growing stock–The main stem of growing-stock trees between a 1-foot stump height and the growing-stock top. Also called the merchantable stem.

Growing-stock top–The point on the main stem of a growing-stock tree above which industrial products cannot be produced. The minimum growing-stock top is 4.0 inches d.o.b., or the point at which the main stem breaks into branches if this occurs before it reaches the top diameter.

Growing-stock tree–A live tree of commercial species 5.0 inches d.b.h. or larger, that contains at least one 12-foot sawlog or two 8-foot noncontiguous sawlogs, and meets regional specifications for freedom from defect. Excludes rough cull trees and rotten cull trees.

Growing stock biomass–The weight of wood and bark in growing stock. Includes sawlog biomass and upper stem biomass.

Merchantable stem–The main stem of growing-stock trees between a 1-foot stump height and the growing-stock top. Also called growing stock.

Moisture content–In wood, the amount of water present, generally expressed as a percentage of its oven-dry weight.

Nontimber–Trees that are not timber, such as salvable dead trees, seelings, and saplings. Does not include shrubs, which are not trees.

Other forest land–Forest land other than timberland; includes reserved, unproductive, and urban forest land.

Oven-dry–The process whereby green wood has had moisture removed in a kiln through the use of artificial heat, in the range of 102º to 105ºC.

Poletimber–Growing-stock trees at least 5.0 inches d.b.h., but smaller than sawtimber trees.

Reserved forest land–Forest land withdrawn from timber utilization by administrative designation, such as parks or exclusive use for Christmas trees.

Roots–The entire below ground portion of trees.

Rotten cull tree–A live tree of a commercial species, 5.0 inches d.b.h. or larger, that does not meet regional specifications for freedom from defect primarily because more than 50 percent of the tree is rotten.

Rough cull tree–A live tree of commercial species 5.0 inches d.b.h. or larger (or a live tree of a noncommercial species), that does not meet regional specifications for freedom from defect primarily because of poor form.

Salvable dead tree–A dead tree 5.0 inches d.b.h. or larger that has died recently. Many branches remain and the bark is still intact (it is generally very tight and difficult to remove from the tree).

Sapling–A live tree less than 5.0 inches d.b.h., but larger than 1.0 inch.

Sawlog–The main stem of a sawtimber tree between the stump height and the sawlog top.

Sawlog top–The point on the main stem of a sawtimber tree above which a sawlog cannot be produced. The minimum sawlog top is 7.0 inches d.o.b. for softwoods and 9.0 inches d.o.b. for hardwoods.

Sawtimber–Growing-stock trees at least 9.0 inches d.b.h. for softwoods or 11.0 inches for hardwoods, containing at least one 12-foot sawlog or two noncontiguous 8-foot sawlogs, and meeting regional specifications for freedom from defect. Small sawtimber is less that 15.0 inches d.b.h.; large sawtimber is greater than or equal to 15.0 inches d.b.h.

Seedling–A live tree less than 1.0 inch d.b.h., and that is free to grow.

Shrub–A live plant that has a persistent, woody stem and relatively low growth habit, and that generally produces several basal shoots. Differs from a tree because of its low stature and nonarborescent form.

Snag–A dead tree 5.0 inches d.b.h. or larger that has been dead for some time. Most of the bark may be missing, or the tree may be covered with bark that is very loose (it can be removed with little effort).

Sound cull–Defect that is free from decay. The defect may lower the timber's utility or commercial value, relegating it to a lower grade, but does not cause its rejection. It may be a blemish or imperfection such as stain that may be acceptable by regional standards, or cull such as crook or sweep which affects only the board-foot volume of a log.

Specific gravity–As applied to wood, the ratio of the oven-dried weight of a wood sample to the weight of a volume of water equal to the volume of the sample at a specified moisture content (green, air-dried, oven-dried).

Stump–The main stem of living trees 5.0 inches d.b.h. and larger, between the ground and a 1-foot height.

Timber–All living trees 5.0 inches d.b.h. and larger, including growing-stock trees and cull trees.

Timber biomass–The weight of wood, bark, and foliage in growing-stock trees and cull trees. Includes the biomass of all tree components above and below the ground such as the merchantable stem, unmerchantable stem, branches, twigs, stump, and roots.

Timberland–Forest land producing or capable of producing annual crops of industrial forest products (at least 20 cubic feet per acre per year). Does not include productive-reserved land. Currently inaccessible and inoperable areas are included except when the areas involved are small and unlikely to become suitable for production of industrial wood.

Tree–A woody plant that has a well-developed stem and is usually more than 12 feet high at maturity.

Unmerchantable stem–The main stem of growing-stock trees above the growing-stock top.

Unproductive forest land–Forest land that is incapable of producing 20 cubic feet per acre per year of industrial wood under natural conditions, because of adverse site conditions (also called woodland).

Upper stem–The main stem of sawtimber trees between the sawlog top and growing-stock top.

Urban forest land–Forest land that is surrounded by urban development (not parks) whether commercial, industrial, or residential.

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Wharton, Eric H.; Griffith, Douglas M. 1993. **Methods to estimate total forest biomass for extensive forest surveys: applications in the northeastern U.S.** Res. Pap. NE-681. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 52 p.

Presents methods for synthesizing information from existing biomass literature when making biomass assessments over extensive geographic areas, such as for a state or region. Described are general applications to the northeastern United States, and specific applications to Ohio. Tables of appropriate regression equations and the tree and shrub species to which these equations can be applied are presented.

Keywords: forest inventory; weight estimation; tree biomass; forest biomass; shrub biomass; regression equations

Headquarters of the Northeastern Forest Experiment Station is in Radnor, Pennsylvania. Field laboratories are maintained at:

Amherst, Massachusetts, in cooperation with the University of Massachusetts

Burlington, Vermont, in cooperation with the University of Vermont

Delaware, Ohio

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