Biomass Sampling Protocol for Broadleaved Deciduous Species – FIA Study Plan - Draft 1- 06182012

Sample Tree Selection

Species selection is based on ranks of growing stock volume in eastern or western regions. Species identified for southeastern United States for the 2012 field season include red maple (*Acer rubrum* L.) and white oak (*Quercus alba* L.). Additional species and species groups will be selected in subsequent years to comprise 70% of growing stock.

Site selection in the 2012 field season should take into consideration opportunities for working in sites, stands, and tracts where accessibility and proximity to laboratory facilities are favorable. We hypothesize that differences in ecological and edaphic factors will have significant relationships with aboveground tree biomass and carbon content; however, the focus in year 1 is the development and testing of procedures that will be most efficacious in quantifying the nature of these relationships over a broad geographical extent.

Tree selection should account for the widest range of ecological and edaphic factors possible, given the opportunities available for selecting sites in year 1. At minimum, trees selected should span one order of magnitude in dbh, e.g., spanning a range from 3 to 30 inches, and uniformly cover the range of dbh with gaps generally no larger than 2" in the sample range. Trees should be selected from as many as possible of five canopy position categories for forest-grown trees – open-grown, dominant, codominant, intermediate, and suppressed – recognizing that it may not be possible to sample all tree sizes in all canopy positions. To the extent possible, when more than one tree is selected in any 2" diameter class, variation in their heights and crown architectures – numbers, sizes, and heights of branches – should be as large as possible. While trees exhibiting defects such as hollow stems, broken tops or branches, poor form, etc., can be selected, the majority of sample trees should be relatively free from major defects of this type.

Measurements of Stand and Site Attributes

The geographic coordinates of each sample tree should be collected using a GPS receiver accurate, nominally, to within ± 10 feet. Where possible, GPS coordinates should be corrected using DGPS to achieve accuracy within ± 5 feet.

A circular plot of radius 24 feet, centered on the subject tree pith, shall be used to determine the numbers, sizes (dbh and height), and species of all neighboring trees ≥ 4" dbh. Where several subject trees will be selected for measurement in close proximity to each other, it may be advantageous to construct a stem map extending out 24' from any of the subject trees.

Timing of Measurements

Foliage biomass can only be measured in deciduous broadleaved trees during the summer growing season when foliage is fully displayed; however, when foliage biomass observations are not needed, considerable effort can be saved by making observations during the dormant season.

Growing season measurements should be made following the complete expansion of the initial (spring) flushes of leaves in red maple and white oak, and before the onset of late season (autumn) senescence. Completeness of leaf expansion can be observed directly, or approximated by allowing 4-6 weeks to pass after bud burst. Senescence can be determined based on late-season foliage colors.

Dormant season measurements should be made following autumn leaf drop, and prior to spring bud burst.

Standing Tree Measurements

Standing tree measurements are necessarily limited by the tools and time available to conduct observations without sacrificing the sample tree. Translation of standing tree protocols tested here to an operational procedure is expected; therefore, measurements deemed excessively detailed or inappropriate for operational use will not be considered. Exceptions will be made in the 2012 field season to allow for the development and testing of novel methods or tools.

Tree. The following tree attributes should be recorded for trees to be included in the standing-tree measurements database for the 2012 field season:

- Tree ID (a unique identifier)
- Species (white oak, WO, QUAL, or 802; red maple, RM, ACRU, 316)
- Origin (planted or natural)
- Crown class (open-grown, dominant, co-dominant, intermediate, suppressed)
- D-tape diameter at breast height (dbh; 0.1”)
- Total tree height (0.1’), measured with a staff or tripod mounted Criterion RD 1000.
- Crown width along widest axis, taped or measured with Trupulse 360
- Crown width at 90° offset to widest axis, taped or measured with Trupulse 360

Main Stem. The main stem is generally defined as the largest-diameter branch at a fork or node that ultimately leads to an apical control point (Cost 1978). If it is not clear which branch to consider as the main stem based on diameter and position, then the selection that extends to the highest point will be chosen. When neither distinction can be made, the branch on the observer’s right, or one chosen through a flip of a coin should be classified as the main stem.

The following attributes of the main stem should be recorded for trees to be included in the standing-tree measurements database for the 2012 field season:

- Diameter (0.1”) at stump height (0.5’) as measured by the Criterion RD 1000
- Criterion diameters at heights of 2.5’ , 4.5’, 8’, 12’, 16’ etc. until a 4” or smaller diameter has been measured, or the instrument is no longer capable of obtaining diameter measurements.
- Diameter (0.1”) as measured by the Haglof Gator Eyes at the same heights where Criterion measurements are made. The Criterion operator communicates audibly to the Gator Eyes operator whether the lasers need to be raised higher “up”, or lowered “down”

Branches. (First order) branches are those that originate along the main stem and are at least 0.5" in diameter at their origin. The following attributes of first-order branches should be recorded.

- Branch number (unique integer starting with 1, typically increasing with branch height).
- Branch height, measured with the Criterion
- Branch diameter, measured with Gator Eyes, measured away from the branch collar and perpendicular to the branch pith to avoid swelling near the collar.
- Branch length, base to tip, measured with the TruPulse 360.
- Vertical and horizontal components of branch length, measured with Criterion and TruPulse 360, or comparable trigonometric-based devices (hypsometer/inclinometer for vertical distance, electronic compass, transit, or angle encoder for measuring horizontal distances.)

Felled Tree Measurements

Following completion of the standing tree measurements, the tree will be felled at or below the 0.5" stump height. A Humboldt notch is preferred, when possible, to preserve the bole section above the stump height. Once the tree is safely on the ground, the following measurements will be made.

Tree. The taped total height of the tree, including the 0.5" stump height.

Main Stem.

The following attributes of the main stem should be recorded based on taped heights, where the taped heights are aligned with the standing tree measures, e.g., stump height breast height, 8', 12' etc.

- Caliper diameter (0.1") at stump height (0.5') as measured by the tape.
- Caliper diameters at taped heights of 2.5' , 4.5', 8', 12', 16' etc. until a 4" or smaller diameter has been measured.
- Chalk or crayon marks can be helpful when made at the measurement points, for subsequent bucking of the stem into sections for weighing. A single caliper diameter measurement may be made across the most-accessible face of the fallen log (usually the side facing up).

Branches. The following attributes of first-order branches should be recorded.

- Branch number. In cases where a branch was unobserved while the tree was standing, a new ID will be assigned. The standing-tree attributes for this branch will be recorded as "missing." In the case where a branch observed while the tree was standing cannot be identified (due to breakgage, penetration into the ground, or an observer error) the felled-tree ID and measurements can be recorded as "missing." In all other cases, the felled-tree and standing-tree branch IDs should match each other.
- Taped branch height (0.1').
- Branch diameter (0.1"), measured with calipers, measured away from the branch collar and perpendicular to the branch pith to avoid swelling near the collar
- Taped branch length (0.1'), straight line, base to furthest tip.

- Small printed labels with the branch ID stapled near the base of each branch can be helpful for subsequent identification if affixed before the branches are cut from the stem.

Dissected Tree Fresh Measurements

Stem Sections.

Stem sections are numbered consecutively with integers starting with the first section cut above the stump. Marking each section number on the cut surface, large end, is helpful for avoiding mix-ups during subsequent handling and processing. Other than section 1, heights of the small ends (tops) of each section should correspond to tape-measured heights of (section #) × (4 feet). The following measurements should be recorded from each stem section.

- Length (0.01'), measured with a tape. Tape placement should account for any sections cut at angles slightly off from 90° with the length of the section.
- Lower surface – generally the large end – diameter, average of two caliper readings (0.1").
- Upper surface – generally the small end – diameter, average of two caliper readings (0.1").
- Green (field) weight (lb) measured to 3 or more significant digits.
- Interior defects should be measured across a cut surface in two directions, the average of which is recorded (0.1"), along with the approximate length of the defect along the length of the section (0.1 ft). Record defect type as one of the three classes:
    1. Discolored, e.g., injury scars, but wood appears sound
    2. Some decay and loss of mass (unsound)
    3. Extremely unsound (dust or powder) or hollow

  Note: coloration due to heartwood is not considered a defect

Stem Disks.

One or more disks (1" to 3" thickness) should be cut from each stem section for the purpose of determining dry-to-green weight ratios and basic density measurements. When saw-kerf loss measurements by weight are desired, a convenient method is to make three saw cuts near the stem-section midpoint, about 2" apart. The three cuts produce two disks, which should be labeled with the section number and letters A and B.

Unitless dry-to-green weight ratios determined from disks will be used to estimate stem-section dry weights without having to oven-dry entire sections. Collection of disk specimens at regular intervals up the stem allow for determination of any systematic variation in moisture content or basic density with stem height. Collection of two or more disks in a single section allow for additional characterization of variance in moisture content or basic density within sections.

The following green measurements should be recorded from each disk as soon as possible after felling. Disks not immediately available for measurement should be stored in sealed plastic bags or containers and kept cool to avoid moisture loss, shrinkage, or molding.

- Midpoint green diameter, large axis, measured with calipers (mm).

- Midpoint green diameter, 90° from large axis, measured with calipers (mm).
- Disk thickness (0.25 mm) average of four caliper measurements spaced uniformly around the disk circumference.
- Green weight (g), recorded to 3 or more significant digits.
- Interior defect diameters should be measured across the cut surface in two or more directions, the average of which is recorded and classified as 1) sound, 2) unsound, or 3) hollow.

Note: U.S. standard units (0.1 inches, 0.1lb) may be used, but effort should be made to maintain 3 significant digits in disk measurements.

Fresh Bark Measurements (optional).

Fresh bark measurements provide a means to develop estimators for green bark weight and volume, along with inside bark green weight and volume. On sample disks selected for fresh bark measurements, bark should be carefully removed as soon as possible after felling and the following additional disk measurements should be recorded:

- Disk ID
- Inside-bark midpoint diameter, large axis, measured with calipers (mm).
- Inside-bark midpoint diameter, 90° from large axis, measured with calipers (mm).
- Fresh bark weight (g)
- Wood-only green weight (g)

Note: U.S. standard units (0.1 in, 0.05 lb) may be used, but effort should be made to maintain 3 significant digits in disk and bark measurements.

Kerf Weight (optional).

Kerf weight losses can be important to account for biomass lost during the dissection of stems and large branches. Saw kerf weight loss can be measured in the field by subtracting stem weight sections before and after cutting disks, and dividing by the number of cuts made (Figure 1). Due to the relatively low resolution of affordable field scales, it is recommended that multiple saw cuts be made for each difference calculation. A convenient method is to make three saw cuts through the stem near the section midpoint, about 2" apart, producing two disks. The following weight measures and calculations are then made.

- Denote stem section green weight as GW_1.
- Following cutting of disks, weigh remaining stem section(s) and disk(s) together, denoted as GW_2.
- Denote the number of kerf channels (cuts) made as k.
- Compute the average kerf weight (KW) as $KW = \frac{GW_1 - GW_2}{k}$.
- Record the representative diameter (0.1") of the stem where the kerf cuts were made.
- Record the chainsaw chain width or relevant specifications (pitch/gauge/cutter type).

Figure 1. Example of green-weight measurement following cutting of a single disk from a 4’ log section. Subtracting the weight of this measurement from the log-section weight made before cutting the disk gives the weight of two sawkerf cuts through the log.

Branches — Leafless (dormant season).

The green (field) weight of each first-order branch should be measured in the field and recorded alongside the branch number. It may be necessary to section branches to fit them into the scale apparatus or weigh in stages, then sum the weights. When removing branches from the main stem, chainsaw cuts should be made that generally preserve the stem form (Figure 2). The whole branch weight to be measured is

- Whole branch green (field) weight (0.05 lb).

Following weighing, small branches may be clipped using shears or loppers and placed in labeled paper bags or boxes for subsequent transportation and drying. Large branches may be further processed by subsampling (see *Optional Subsampling* next section).

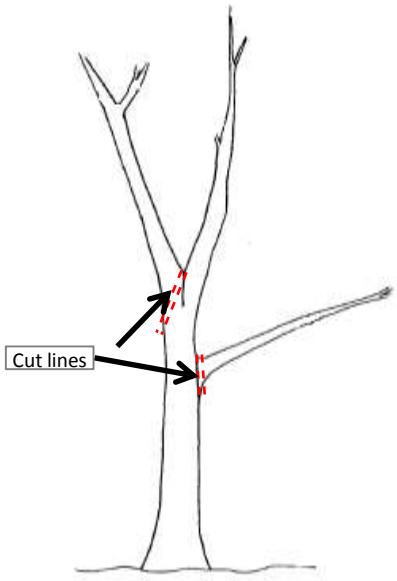

Figure 2. Example of branch cut lines for preserving stem profile.

Optional Subsampling. For large branches, some subsampling of the branch material may be required to reduce the amount of material to be transported and dried. The subsample weight to be measured is

- Branch subsample green (field) weight (0.05 lb).

Following weighing, the subsample should be clipped using shears, loppers, or saws and placed in labeled paper bags or boxes for subsequent transportation and drying.

Branches with Leaves (growing season).

Separation of leaves from branches is generally not practical in the field; therefore, the processing of branches during the growing season should be done in steps to provide a way to distinguish between dry weights of branch foliage and wood components. The field procedure below, listed as a sequence of steps, provides a means to accomplish this goal.

A) Cut branch from the main stem, recording dimensional measurements and branch ID.
B) Over a suitably sized tarp, prune small leaf-bearing twigs from the branch using hand pruners or loppers.
C) Place leaf-bearing twigs and all foliage material in labeled paper bags or boxes for subsequent transportation and drying.
D) Weigh the remaining leafless parts of the branch in the field and process, using subsampling as needed, for subsequent transportation and drying (see section Branches — leafless).

The partial (leafless) branch weight (step D) to be measured in the field is

- Partial branch green (field) weight (0.05 lb).

Following weighing, the partial (leafless) branches may be clipped using shears or loppers and placed in labeled paper bags or boxes for subsequent transportation and drying. Large partial branches may be further processed by subsampling (see *Optional Subsampling* next section).

Figure 3. A leafless portion of a first-order branch following excision of leaf-bearing twigs (on tarp).

Optional Subsampling. For large partial (leafless) branches, some subsampling of the branch material may be required to reduce the amount of material to be transported and dried. The subsample weight to be measured is

- Partial (leafless) branch subsample green (field) weight (0.05 lb).

Following weighing, the subsample should be clipped using shears, loppers, or saws and placed in labeled paper bags or boxes for subsequent transportation and drying.

Green Foliage Weights (optional).

Measurements of green foliage weights followed by subsequent drying and reweighing, provide a means to estimate the green weight of foliage by branch or whole tree. Since it's generally impractical to separate all the leaves from a branch while fresh, a subsample of leaves should be collected from each branch selected for green foliage weight measurement, recording:

- Branch ID
- Subsample ID if more than one sample is collected per branch
- Foliage fresh weight (g)

Dry Weight Measurements.

Dry weight measurements should be recorded in the same units and same decimal precision as green weights were recorded, whether in the field (branches, branch subsamples) or laboratory (disks, bark). Drying oven temperatures should be set between 100° – 105° C. Oven-dry condition of specimens should be by verified by noting that no appreciable weight change occurs over a 24 hr period. A separate document, Equilibrium Moisture Content in Wood Specimens, describes a procedure for adjusting weights of specimens dried at oven temperatures lower than 100°C.

- Disk dry weight (g) recorded to 3 or more significant digits.
- Bark dry weight (g), when applicable
- Bark-free disk weight (g), when applicable
- Branch wood (with bark) dry weight (lb), recorded to 3 or more significant digits.
- Branch subsample wood (with bark) dry weight (lb), recorded to 3 or more significant digits.

Twig and foliage specimens (see section Branches with Leaves) from each branch are oven-dried and sorted to separate the leaf & twig components (Figure 4). Twig dry weights must be attributed to the corresponding branch they were excised from to properly determine the dry weight of wood & bark of each branch. Foliage dry weights are also attributed to the corresponding branches they were excised from. In cases where subsamples of foliage were (optionally) weighed green (see section Green Foliage Weights), their weights must be recorded in the subsample database, then also attributed to the total foliage dry weight for the branch from which they were taken.

- Twig dry weight (lb) by branch, recorded to 3 or more significant digits.
- Foliage dry weight (lb) by branch, recorded to 3 or more significant digits.
- Foliage subsample dry weight (g), when applicable.

Bark Measurements.

Two biomass attributes that require the measurement of bark are I.) the dry weight contents of bark, e.g., as a fraction of total tree weight, or as a fraction of the weight of a cross-section cut from a stem or branch, and II.) the volumetric contents of bark in relation to outside-versus-inside-bark green volumes of stems or branches. While both I. and II. require separating bark from wood, weight determinations are flexible to allow separation of bark from wood either before or after specimens are oven-dried. Volumetric measurements should be made prior to drying to avoid irreversible dimensional changes. In cases where separating bark from disk specimens while fresh is not feasible, partial information can be obtained by separating bark from disks after drying.

Bark weight.

Bark weight determination as a fraction of stem cross-section can be made conveniently on disk sections after their ovendry weights have been recorded. Using a chisel or other sharp instrument, bark should be removed from the disk specimen. It may be necessary to bag and re-dry the separated bark to oven-dry condition again before re-weighing. Several measurements required for determining bark fraction of a disk are identical to the standard the disk measurement protocol (see section Stem Disks). In addition, bark dry weight should be recorded.

- Bark dry weight (g), 3 or more significant digits

Pairing bark dry weight with disk dimensional and dry weight measurements ensures that bark-weight:disk-weight ratios can be computed for sample disks of any diameter. Further, the dry weight of bark per unit of green disk volume can be computed for sample disks or sections of wood of varying diameters.

Figure 4. Dried leaf-bearing twigs being sorted to separate foliage from branch wood and bark (twig) material.

Optional Detailed Stem and Branch Measurements.

Randomized branch sampling (RBS) and importance sampling (IS) from whole-tree taper models are candidate procedures for estimating whole tree and component biomass without separating and weighing tissues from whole trees. The following optional measurements can aid in assessing the precision of either method. In addition, since whole-tree taper models are seldom available (e.g., Van Deusen and Roesch, 2011), detailed measurements from felled trees can be collected here for that purpose.

A meaningful numbering system for RBS segments branches assigns integers 1, 2, 3 etc. to segments that originate from a single node. For consistency, the integer digits are assigned in descending order of the segment diameter, i.e. the largest stem or branch at a node is numbered 1 and the next largest branch is numbered 2, etc., but this ordering is not strictly necessary. Following the RBS layout, the main

stem below the first node is numbered as segment 1. Its dimensions and green weight are measured from the stump to the cut points immediately above the first node (Figure 5, cut points d and e). The digit 1 is preserved to serve as the ID of the node from which the next two segments originated. They are distinguished from one another by a new digit (either 1 or 2) appended to their originating node ID. At each node encountered, a new digit is appended to the path ID accumulated to that point. The ID of a terminal segment includes identifying information for all the segments followed as a path is traversed from base to tip. For example, the terminal segment 1121 (Figure 5) followed a path through stem segments 1 and 11, branch segment 112, and finally branch segment 1121.

Measurements to be made for each segment include

- Segment diameter, measured at the cut point.
- Segment length from lower to upper cut points, lower cut point to branch tip for terminal segments.
- Dry weight of foliage removed from segment.
- Dry weight of wood and bark (foliage removed) from segment.

An additional pair of measurements to collect from each stem or branch segment includes the segment diameter immediately below its upper node, along with the length along the segment from its base to the measurement point. These measurements can be used to parameterize whole-tree taper models that represent accumulated cross-sectional area of stem and branch material at specified distances from the stump. In Figure 5, the optional segment length (between cut point “g” and the point immediately below the upper node) of segment ID 111 is labeled, along with the point of measurement for its diameter.

- Segment length to a point immediately below the upper-node
- Segment diameter below upper node

Additional measurements of branch segment diameters at specified distances along segments may optionally be collected. Presumably, any additional measurement pairs would be collected on relatively long (e.g., > 2 ft) branch or stem segments.

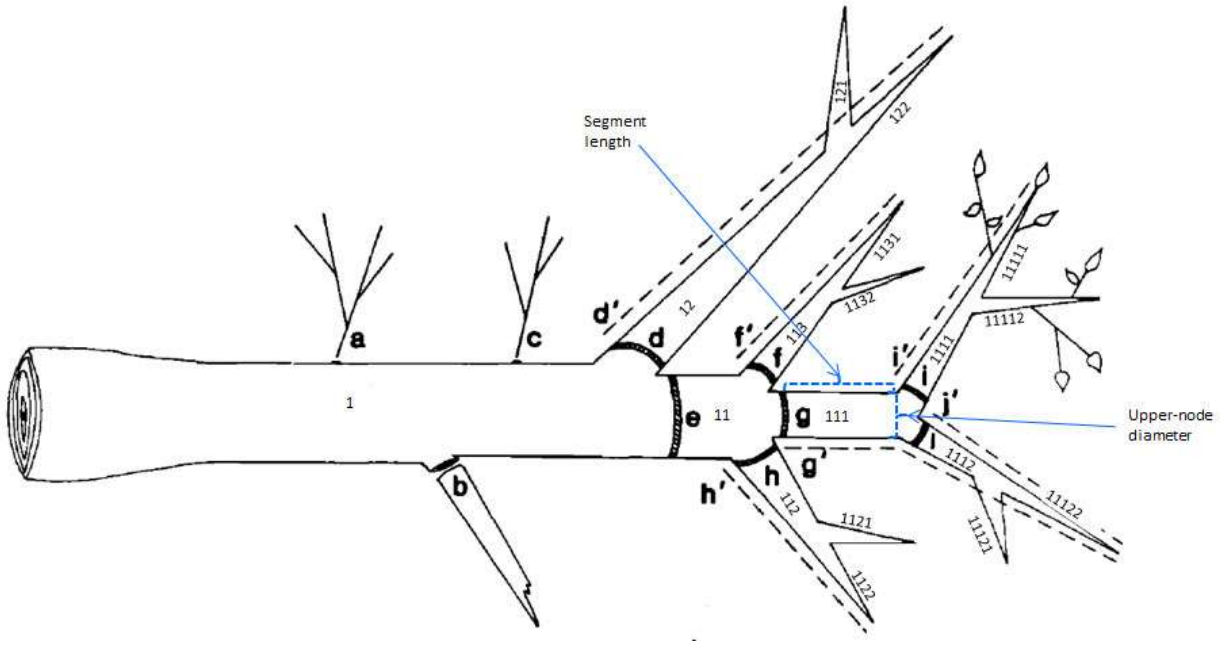

Figure 5. Identification of tree stem and branch segments in randomized branch sampling.

References

Van Deusen P, Roesch FA, 2011. Sampling a Tree for Total Volume, Biomass, and Carbon. Journal of Forestry 109:131-135.