Standardized Inventory Methodology

Version 1.0

Notes on this document and its use:

*This Methodology is meant to be a companion document for optional use by users of the **Forest Project Protocol V4.0 and any subsequent program updates.** Although this Methodology has been pre-verified for use by projects registering under V4.0 of the Protocol to simplify the verification process, the implementation of the Methodology is still subject to review for conformance to these standards at the project level. In situations where this document contradicts the Protocol, the Protocol always takes precedence. This document will be updated periodically, and the Reserve welcomes feedback and suggestions to assist with those updates. If you have comments, please send an email to policy@climateactionreserve.org.*

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1 Preface

This Standardized Inventory Methodology (SIM) was developed in tandem with a computer application referred to as Climate Action Reserve Inventory Tool (CARIT). Both were developed with funding from the Conservation Innovation Grant program of the U.S. Department of Agriculture's Natural Resources Conservation Service, as well as with in-kind support from the Redwood Forest Foundation, Inc. and The Climate Trust. The goal of the SIM and CARIT are to reduce project development and management costs to increase participation among marginalized landowners.

This document is a companion document to the Forest Project Protocol (FPP), Version 4.0, as well as any subsequent program updates (e.g., Version 4.1), of the Climate Action Reserve (Reserve). There are many references to sections and definitions in the Protocol. Capitalized words in this document are included in the glossary of the Protocol unless otherwise defined here within.

2 Introduction

2.1 Objectives for Standardized Inventory Methodology

This SIM was created to improve the overall efficiency of inventory implementation and verification. It has been developed through experience in observing key elements of inventory standards and methodologies that have performed well for carbon projects, and through consultation with experienced project developers, verifiers and forest mensuration experts. This methodology was shaped by a variety of considerations, including:

- Establishing a methodology that is suitable for use in a variety of forest conditions;
- Maximizing the probability of achieving consistent results in consecutive plot measurements, including those between project developers and verifiers, as tree growth causes expansion factors to change;
- Providing the framework for a streamlined review process for verifiers
- Ensuring consistency with the Reserve's computer application (CARIT) (see Section 2.2 below)

The SIM was developed specifically for establishing and maintaining a forest carbon inventory that is compliant with the FPP and consistent with CARIT. Although landowners typically manage for a variety of goals beyond carbon, such as timber production and wildlife habitat, employing the SIM as it is presented here may not adequately address such goals. While project owners may incorporate additional measurements or components to address non-carbon goals, they must otherwise address and maintain consistency with all aspects outlined below for it to be considered eligible for verification as a Standardized Inventory Methodology.

2.2 CARIT – Climate Action Reserve Inventory Tool

The SIM was developed to be consistent with the Climate Action Reserve Inventory Tool (CARIT) for calculating and maintaining a project's carbon inventory. CARIT is available at no cost on the Forest Project Protocol section of the Climate Action Reserve's website (http://www.climateactionreserve.org/how/protocols/forest/), along with supporting documentation to assist users of the tool.

The use of CARIT is not a FPP requirement. However, both CARIT and the SIM are intended to provide an efficient and cost-effective process for inventory development and implementation, as well as for verification. Verification services only need to confirm that the methodology was correctly implemented. They do not need to verify the inventory methodology is sound or appropriate. Similarly, verification activities that investigate data summaries and reporting only need to ensure that CARIT was not modified by conducting a simple test that ensures the program was not altered. Otherwise, verifiers will not question outputs from the application. These aspects of the standardized inventory approach, and its coordinated use with CARIT, will save project developers both money and time.

3 Project GHG Assessment Boundaries

The FPP identifies Greenhouse Gas (GHG) sources, sinks, and reservoirs that must be included in inventory reports to calculate GHG reductions or enhancements and demonstrate compliance with Natural Forest Management requirements. This inventory methodology focuses only on those onsite reservoirs (or “pools”) that are required to be measured for all projects – live trees and standing dead trees, for which only carbon stocks and their CO_2 equivalents are estimated. This inventory does not address the unusual cases when soil carbon emissions must also be quantified.

4 Stratification

4.1 Stratified Versus Unstratified Sampling

The biomass equations used to calculate carbon have been developed by the United States Forest Service’s Forest Inventory and Analysis (FIA) program. The FIA program has developed biomass equations by species within FIA ‘Regions’, a geographic area that is served by each FIA regional office. Each project must be stratified by the FIA Regions it falls in since trees of the same species may use a different biomass equation depending on the FIA Region in which each tree is found. Additionally, projects must be stratified by Assessment Area if their project comprises multiple Assessment Areas. Assessment Areas are described in Section 4 of the FPP.

Beyond the required stratification by FIA Region and Assessment Area, Project Owners may choose between a stratified and un-stratified sampling design for their forest inventory. Further stratification by forest vegetation condition allows for the calculation of separate estimates for each stratum as well as a combined estimate for the population across all strata. The focus of stratification for a forest carbon project is typically based on variations of carbon stocking, rather than the identification of forest strata for commercial timber operations, which may focus on variation of age class or the stocking levels of commercial species. Stratified sampling will result in population estimates with improved sampling errors compared to those achieved without stratifying for variations in forest vegetation conditions for a comparable sampling effort and, therefore, may reduce sampling costs.

4.1.1 Requirements for Stratified Projects

Where forest vegetation is stratified as part of the inventory methodology, a description of the guidelines used for stratification must be provided, as well as the process for updating stratification and plot associations with strata over time as vegetation conditions change due to harvest, natural disturbances, and growth (see Section 3.2.3). A map of forest strata at the project commencement date must be included in the Project Design Document and re-submitted as part of any site-visit verification.

Project Operators may initiate a project without a vegetation stratification system in place (excepting required stratification for multiple FIA Regions and/or Assessment Areas the project may be in) and transition to a stratified inventory (by vegetation). However, they must accomplish the stratification within one Reporting Period and undergo a site-visit verification for the Reporting Period for which the stratified inventory is reported the first time.

4.2 Stratification Process

4.2.1 Stratification Basis

If stratification is included, the exact guidelines for defining strata polygons must be outlined in the project's methodology. Typical components of stratification rules for timber management purposes include divisions of vegetation based on species associations, tree size classes, and canopy density. However, stratification for carbon inventories may differ from stratification for operational timber management. For simplification, and to maintain the focus of the inventory on producing quality estimates of forest carbon stocking, the approach to stratification recommended here is to stratify by relative carbon stocking. It is recommended to limit the number of strata to five classes to avoid disputes that surface when attempting to achieve higher levels of granularity in relative carbon stocking. An example of relative carbon stocking levels within the project based on generalized stocking density classes is:

- Very High
- High
- Medium
- Low
- None

Stocking density ranges should be assigned to the above stocking classes according to the *potential* distribution of carbon stocking in the standing live and dead tree pools and must be clearly outlined in the project documentation. The use of the potential carbon stocking distribution is meant to indicate that the current forest vegetation conditions may not represent the range of variation that may arise from management activities, natural disturbances, or forest growth.

4.2.2 Defining Strata Boundaries

Stratification rules are intended to be guidelines for the development of strata polygons that define the spatial extent of the relative carbon levels across the landscape. Analysts performing the stratification do not always have the advantage of having empirical data. Instead, they often rely on experience, observations, and remotely-sensed data to delineate stratum boundaries according to the stratification rules. As such, the application of a given set of stratification rules on the same project area by two different analysts would likely result in similar but varying strata boundaries being drawn.

The definition of strata boundaries should be conducted where detectable variation in relative carbon stocking, through remotely-sensed data or field-based knowledge, is identified in areas greater than 10 acres. That is, the minimum mapping unit for identifying variation in vegetation should be 10 acres. Non-forest areas that are not expected to be forested (e.g., rock outcrops) during the project lifetime but are smaller than the specified minimum mapping unit are acceptable as a stratum, though it is suggested that such areas simply be excluded from the Project Area. Roads and landings should be included in the polygons of an adjacent stratum unless the road or landing exceeds 10 acres. Where strata boundaries have been made on roads or landings due to variation in vegetation characteristics on either side of the road, the boundaries should remain constant unless and until the vegetation characteristics on both sides of the road are considered the same.

4.2.3 Updating Strata

Forest vegetation is in constant flux because of harvest, natural disturbances, and growth. Updates to strata assignments (labels) and boundaries will be required as changes occur to the project area that make existing strata delineations inaccurate. Since harvest and natural disturbances can produce rapid changes in conditions, updates to the stratification should be made within the same Reporting Period in which such an event occurred, if feasible, to ensure the inventory is as up to date as possible. Plots associated with harvested or disturbed areas should also be remeasured as soon as possible, though such plots (up to 5 percent of the total inventory plots) may also be excluded for one Reporting Period, per Section 2.2.2 of the Quantification Guidance document that accompanies the FPP.

Updates to strata boundaries and assignments must follow the same stratification rules specified in the project's inventory methodology. The overall stratification shall be reviewed by the Project Owner every 12 years at a minimum to ensure strata labels address any changes in vegetation that may have occurred due to forest growth.

5 Inventory Confidence

All projects are held to high standards of inventory confidence. CO_2e per acre is the target variable for determining inventory confidence. The target level of confidence for the overall inventory is a sampling error of ±5 percent at the 90 percent confidence level, with a deduction applied to the onsite stock estimate of a project if the sampling error is greater than 5 percent. Projects must maintain a minimum confidence standard of a standard error of ±20 percent of the mean estimate at the 90 percent confidence level to remain eligible for credit issuance; a standard error greater than ±20 percent requires a 100 percent confidence deduction of onsite stocks, which will result in a reversal of any previously issued credits.

The number of plots required to achieve the overall goal of a sampling error of ±5 percent at the 90 percent confidence level will vary based on the variability of stocking within the Project Area. Project Owners are responsible for estimating the number of plots needed to achieve the target sampling error. The sampling error may change over a project's life. In such cases, the Project Owner may wish to optimize the number of plots measured to achieve the desired inventory confidence.

6 Plot Sampling Procedures

6.1 Establishment

Potential plot locations are developed within a GIS on a 2 chain by 2 chain grid of random origin that uniformly covers the Project Area, with grid points clipped to the Project Area. All potential plots shall be submitted with the Project Design Document and will remain in place for the life of the project. The plot identifiers and their latitude and longitude coordinates will be stored permanently in a data repository assigned by the Project Operator.

Actual plots used for sampling are selected randomly from the pool of potential plot locations. All potential plot locations should be organized in random order using a computer application. If the inventory is stratified, plot order will be randomized within each stratum. The list of plots in random order must be submitted to the Reserve prior to initiating sampling activities in the field. Project Owners must decide how many plots on the list to sample based on the variability in their forest and whether the inventory is stratified. Ideally, the complete list of plots needed to achieve the confidence targets (described earlier) is known so that Project Operators can map the plot locations and develop an efficient strategy to locate plot locations in the field and collect measurements.

Plots do not need to be sampled in the order they are found on the list but only consecutive plots from the randomly sorted plot data can be used for developing CO_2e and confidence estimates. If the desired confidence is not achieved with the initial sample size, additional plot locations can be added to the pool of sampled plots by selecting additional plots from the randomly ordered list of potential plot locations.

Plots are sampled where they lie, except as outlined in Section 6.3 below.

6.2 Navigation to Plot Centers

The goal of navigational guidance is to ensure a standardized approach to locating plot centers in the field. Since GPS units are imperfect in terms of pinpointing a location under a forest canopy, cruisers must adopt techniques that ensure the plot center is established without bias. The cruiser shall find a location that provides for a good signal when a GPS receiver indicates the cruiser is between 50 and 100 feet away from the plot center, though further distances may be used if conditions do not allow for an adequate reading within this distance. Using the GPS "Go To" function which displays distance and bearing to plot center, the cruiser shall measure the distance to the plot center using a steel loggers tape, hip chain, or electronic device in the direction indicated on a handheld compass.

The GPS unit shall not be used to locate the exact plot center in the field. The mapped plot location and its coordinates are not intended to indicate the absolute position of the plot center, but rather serve as a guide for locating (and finding again) the plot center in the field.

6.3 Special Plot Locations

6.3.1 Hazardous Conditions

Cruisers may find that the random plot location is highly hazardous due to topography, presence of chemicals, criminal activity, or other reasons. In such cases, the cruiser shall record the hazard in the "notes" field of the plot data and select the next plot in the randomly ordered list of potential plot locations as a replacement.

6.3.2 Roads and Landings

Plots landing on roads or landings are sampled where they lie, as specified in Section 6.1. This methodology assumes that roads and landings are part of the strata in which they fall, as opposed to subtracting out the area covered by roads and landings from the gross project acreage. As such, per the random sampling design, the chances of the area encompassed by a road or landing being sampled is equal to the chance of any other area within a given stratum being sampled. Similarly, the conditions represented by plots falling on or encompassing roads and landings are assumed to contribute to the estimate of the carbon stocking of a given stratum in proportion to the area they comprise within that stratum.

All other specifications in this methodology apply to plots landing on roads or landings, including those in Sections 6.3.1, 6.4 and 8.

6.3.3 Watercourses

For the same reasons as stated for plots falling on roads and landings, plots landing in watercourses are sampled where they lie. Similarly, all other specifications in this methodology apply to such plots, including Sections 6.3.1, 6.4, and 8.

6.4 Monumenting Plot Locations

When plots are monumented, verifiers can randomly select monitored plots for evaluation and compare their measurements to landowner data directly in a paired analysis rather than having to develop sufficient confidence in their own sampling to compare to the Project Operator's data. Monumenting plots can save a great deal of time and expense during verification activities.

This methodology requires that plots used for the carbon inventory be monumented. While the plot's coordinates facilitate navigation to the proximity of the plot, other techniques aim to ensure the plot center can be efficiently found again in the future. Properly monumented plots help to ensure that verifiers can base their re-sampling of plots on the exact same plot center as was used during original sampling.

6.4.1 Plot Center Monuments

A rebar stake at least 16" in length shall be installed at plot center. Approximately 4" shall remain above ground and be painted with a high visibility paint. A metal tag shall be attached with wire to the stake indicating the plot number. If it is impossible to install a rebar stake, for example due to the presence of vehicles or foot traffic or the plot falling in a watercourse, the plot will include an additional reference point (below) to locate the plot center.

6.4.2 Reference Points

Two live trees >3.5" DBH, if available, shall be selected that are no closer than 90 degrees apart from each other relative to plot center. Additional reference trees may be added to increase accuracy in the event a previously established plot center needs to be re-monumented. The reference trees should be among the trees sampled on the plot unless there are no trees to select from, in which case trees can be selected from outside the plot area. Using aluminum nails, attach a metal tag at the base of the tree facing plot center and indicating the plot number and the distance (from the tree center at DBH) and bearing (Azimuth) to plot center. Additionally, a highly visible ring shall be painted around the circumference of each bearing tree at the point of DBH measurement, with the plot number painted at eye level. Species, size, and bearing and distance to plot center shall be recorded in the plot and tree data, as outlined in Section 9.

6.5 Plot Layout

Plots used with this methodology, as well as with CARIT, must be fixed area plots. Plots optionally may include a nested fixed area plot for smaller trees. A nested plot is a subplot that is smaller in size than the main plot and shares a common plot center for determining the plot size. Table 6.1 below displays the horizontal radii for common fixed area plot sizes.

Table 6.1. Radii Associated with Various Fixed Area Plot Sizes

Fixed Area Plot Sizes (Acre)	Horizontal Plot Radius (feet)	Comments
1/100th acre	11.8	Common for nested plots that measure the minimum DBH stated in the inventory to a threshold DBH. Trees included in nested plots are considered small and not included in the larger plot
1/50th acre	16.7	
1/20th acre	26.3	Common for inclusion of large trees
1/10th acre	37.2	
$1/5^{th}$ acre	52.7	

Although nested plots may be used, it is important to understand the potential issues that may arise with their use. At the time of verification, trees may grow to a diameter that exceeds the threshold for the nested fixed area. The verifier will evaluate the tree to determine its current expansion factor. Trees changing expansion factors between the time of original measurement and verification can result in substantial changes to plot estimates, resulting in increased verification costs and, potentially, material misstatements about onsite stocks. Considerable growth can occur over the 12-year potential life of the plot, leading to an increased likelihood in disagreement between original sample measurements and those taken by verifiers. Updating plot measurements more frequently will reduce the chances of disagreement between inventory and verification sampling resulting from tree growth.

As indicated in Table 6.1 above, a variety of options are available for fixed area plot sizes. The size selected is determined by attempting to achieve a balance between the variation found within plots and the variation between plots, as well as striving for efficiencies in travel time between plot centers and challenges of ensuring correct area measurements on larger plots where there are steep slopes with heavy brush. Sampling is typically more efficient for smaller plots than larger plots, but the use of smaller plots may require considerably more plots to be sampled to achieve the same level of statistical confidence. The inventory methodology requires that a plot configuration be chosen at the project's initiation and remain consistent throughout the project life unless a complete overhaul of all the plots in the project's inventory is performed.

Nested plots are common on larger fixed area plots ($1/10^{th}$ and $1/5^{th}$ acre) where the time needed to measure small trees is prohibitive and can be reasonably estimated within a smaller plot size. If nested plots are to be used, the methodology must include the size threshold for trees that will be measured only within the nested plot and the size of the nested plot. A suggested approach is to use fixed $1/20^{th}$ acre plots without a nested plot and to measure all trees, thus eliminating the problems associated with nested plots, as discussed above.

6.6 Trees Sampled

The minimum standard indicated in the Protocol for the measurement of live and standing dead trees is the inclusion of trees down to a DBH of at least 5 inches. The recommended minimum DBH for live and dead standing trees for this methodology is 1" DBH. Trees to be measured in nested plots are selected according to threshold decisions made by landowners, as outlined in Section 6.5 above.

7 Order of Measurements

An ordered approach to collecting data facilitates review by field samplers, inspectors, and verifiers. The collection of data shall proceed clockwise from due north. If a nested plot is used in the sample design, the nested (smaller area) plot shall be completed first before continuing with the larger plot. In the case of a tree being directly behind another tree for a given azimuth, the closest tree to the plot center should be measured before measuring the second tree. These rules serve as general guidance and it is understood that there may be trees numbered and registered out of order due to many factors. As such, it is good practice to paint tree numbers on each tree as they are measured.

8 Plots Along Strata Boundaries

As stated above in Section 6, plots are to be sampled where they lie, except in the case of hazardous conditions. However, plots landing near the boundary between two strata or along the Project Area boundary present a special case since a portion of the plot area may fall outside of the stratum containing the plot center, subjecting such plots to boundary overlap issues that create a bias in sampling. Though a variety of methods are available to correct for the bias associated with strata boundaries, plots sampled under this methodology shall employ the "walkthrough method" (Ducey et al. 2004). Among the benefits of the method are that it can be implemented relatively efficiently and can be applied to irregularly shaped boundaries. However, it also likely increases variance, even while it corrects for bias related to boundary overlap. Therefore, Project Operators should be mindful that additional plots may need to be sampled to achieve the desired inventory confidence.

The following key, as adapted from Ducey et al. (2004), is to be used whenever a tree appears close to the stratum boundary to guide the implementation of the walkthrough method. To be clear, as applied in this methodology, the walkthrough method is only employed in situations where plots land near strata boundaries, i.e., not along roads, landings or watercourses, unless such features are coincident with strata boundaries. Figure 8.1 provides illustrated guidance in reference to the key.

I) Is it possible that the tree is closer to the boundary, than to the plot center?

  Ia) NO – No action needed. Tally the tree normally.

  Ib) YES – Proceed to II.

II) Measure the distance from the plot center to the object—call this distance *x*. Now measure the distance from the tree to the stratum boundary, continuing on the same bearing as from the plot center to the tree. Call this distance *y*. Is *y* less than *x*?

  IIa) NO – No action needed. Tally the tree normally.

  IIb) YES – Proceed to III.

III) Does the boundary curve back across the walkthrough line?

  IIIa) NO – Walkthrough point must be outside the tract. Double-tally the tree.

  IIIb) YES – Proceed to IV.

IV) Move to the walkthrough point, so that the distance to the object equals the previously measured distance *x* along the same bearing, or to a point where that location can be clearly identified. Is the walkthrough point inside the tract?

  IVa) NO – Double-tally the tree.

  IVb) YES – Tally the tree normally.

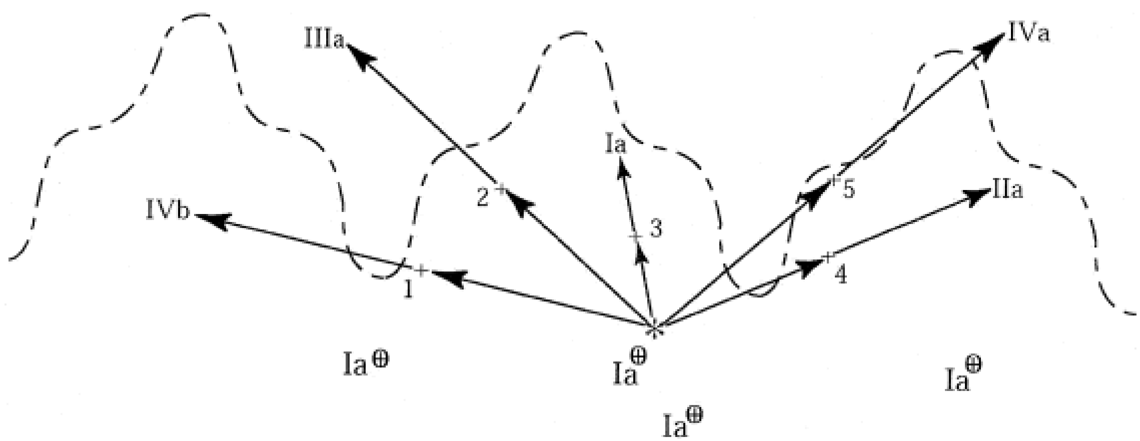


Figure 8.1. Illustration of the Walkthrough Method, excerpted from Ducey et al. (2004).
Five trees (+), lying close to the boundary and, for the purposes of this methodology, assumed to be in the fixed area being sampled, have been tallied from the plot center (*). The arrows indicate the layout of the walkthrough points for each tree; the outcome from the key above is indicated for each walkthrough point. Trees 1, 3, and 4 are tallied normally; trees 2 and 5 are double-tallied. Four objects (⊕) lie "close to the boundary" but in positions where they would be single-tallied, and no measurements would be needed.

9 Data Collection

9.1 Plot Data

Table 9.1 below identifies the data to be entered for each new plot or updated, as necessary, for existing plots.

Table 9.1. Plot Attributes to be Recorded

Item	Attribute	Description
1	Date of plot visit	Date (month/day/year) the plot is sampled
2	Plot number	Enter the plot number for the plot from the identifier used in the plot grid
3	Stratum (FIA Region)	FIA Region in which the plot is located
4	Stratum (Assessment Area)	Assessment Area in which the plot is located
5	Stratum (vegetation)	If Project Area is stratified by vegetation condition, enter stratum assignment prior to sampling
6	Inventory personnel	Enter the initials of the inventory personnel responsible for measuring and recording the plot data (may include more than one person)
7	Latitude (Go To)	Latitude (decimal degrees) from GPS at location 50-100 ft from plot center with good signal reception
8	Longitude (Go To)	Longitude (decimal degrees) from GPS at location 50-100 ft from plot center with good signal reception

Item	Attribute	Description
9	Distance to Plot Center	Enter the distance, in feet, from location with good GPS signal reception to plot center, based on “Go To” function on GPS unit
10	Azimuth to Plot Center	Enter the direction (azimuth), in degrees, from location with good GPS signal reception to plot center, based on “Go To” function on GPS unit
11	Slope	Using a clinometer, average the slope measurements looking uphill and downhill to the nearest 5%
12	Aspect	Enter the degrees (azimuth) looking directly downhill from plot center
13	Plot Type	Normal, no trees, walkthrough
14	Notes	Observations unique to the plot, including: ▪ Proximity to nearby watercourse features ▪ Proximity to nearby skid trails, roads, and landings ▪ Relocation of plot due to hazardous conditions Include descriptors such as approximate distance and bearing to features

9.2 Tree Data

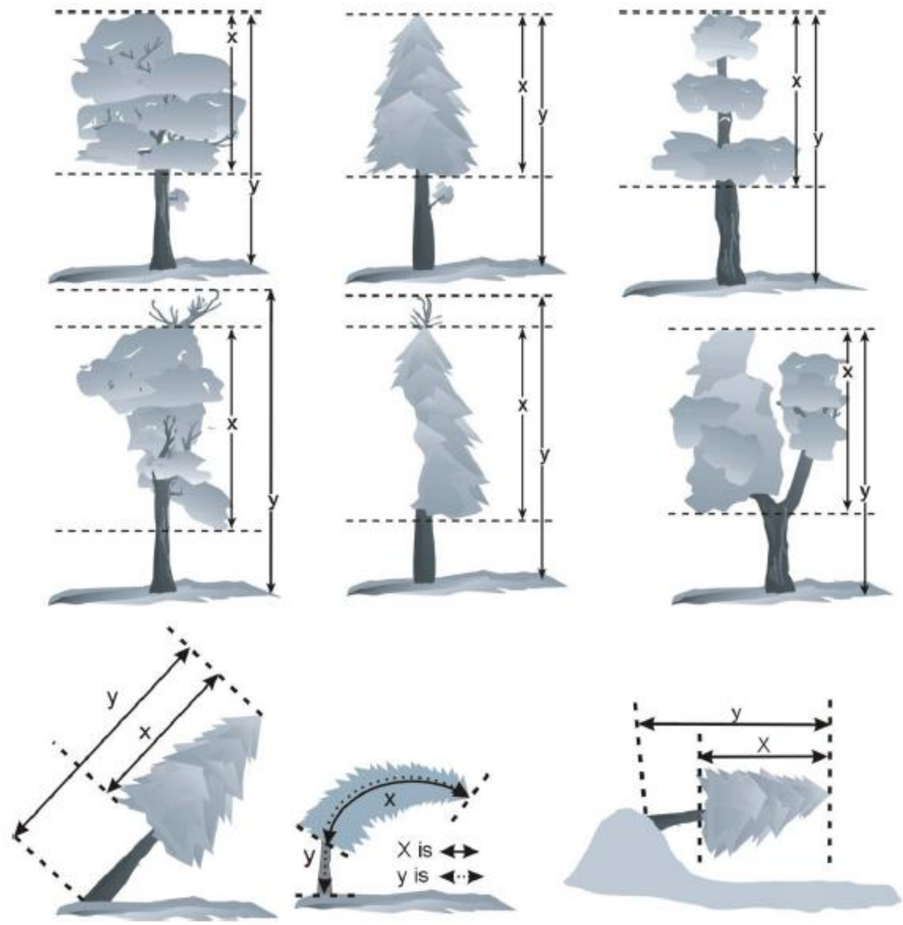
The tree attributes indicated in Table 9.2 are the minimum data requirements for this methodology, as well as for use with CARIT. Other data may be collected as may be required for purposes of baseline modeling or as desired for other management purposes.

Per FPP requirements, all live trees with a minimum of 5-inch DBH shall be measured. All standing dead trees with a minimum of 5-inch DBH and height of 15 feet shall be measured. Smaller live and dead trees may be measured, however, as desired by the Project Owner and specified in the final methodology for the project. Furthermore, a nested plot design may be used according to decisions made by the Project Operator in Section 6.5, including a DBH threshold specified for transitioning between the main plot and sub-plot. If a nested plot is included as part of the inventory methodology, the instructions below for tree measurements will be repeated for both the sub-plot and the main plot. For trees on slopes greater than 9 percent relative to the plot center (as measured from plot center to the tree), the fixed plot radius shall be corrected as outlined in Appendix A.

Table 9.2. Tree attributes to be recorded.

Item	Attribute	Description
1	Tree number	Number of the tree being measured, in order, from directly north of plot center and proceeding clockwise. Trees in nested plot should be sampled prior to those in main plot, with sampling starting from north for each plot.
2	Species	Species for each tree sampled, based on alphabetic species codes as specified in the USDA PLANTS database or numeric FIA species codes, as indicated in Appendix B. Alternatively, users may develop their own species codes. However, such codes should be crosswalked with the species list in Appendix B to ensure consistency with the volume and biomass equations required to calculate onsite carbon stocks, as well as efficient data entry into CARIT.
3	DBH	Diameter at Breast Height, measured to the nearest 0.1 inch at 4.5 feet (breast height) above ground level or root collar on the uphill side of each tree, perpendicular to the angle of the tree. In cases of irregularities at DBH, the

Item	Attribute	Description
		diameter should be measured immediately above the irregularity where it ceases to affect the normal stem form. Illustrated guidance for DBH measurements, including for uncommon trees, is provided in Appendix C, based on the FIA National Core Field Guide (Version 7.2). A horizontal line should be painted on the side of the tree facing plot center at the location of DBH measurement and the tree number painted on the bole facing plot center. If DBH has to be estimated due to impediments preventing direct measurement, record “estimated DBH” in notes field and include a brief description of why an estimate was made. For species requiring measurement of diameter at root collar (DRC) to calculate carbon stocks, diameter is measured at the ground line or at the stem root collar, whichever is higher, and entered into the DBH field. DRC for trees with multiple stems shall be calculated as the square root of the sum of the squared individual stem diameters: $$DRC_{tree} = \sqrt{\sum DRC_{stem}^2}$$ DRC for individual stems should be recorded in the notes field, along with an indication of how the order of stem measurements was determined. Illustrated guidance for DRC measurements is also provided in Appendix C, based on the FIA National Core Field Guide (Version 7.2).
4	Stems	Number of live and dead stems at least 1.0 foot in length and at least 1.0 inch in diameter 1 foot up from the measurement point (required for species for which DRC is measured).
5	Total Height	Measure total height to nearest 1.0 foot from the base of the tree to the tip of the highest branch or point of the tree crown. For broken, dead or missing tops, total height is measured to an imaginary total height, using other trees in the vicinity as a guide. This action must be noted in the notes for the tree. The missing material will be deducted using the tree defect data gathered. Similarly, for leaning trees, an imaginary total height is measured by assuming a point where the tree would be if it were vertical. This action must be noted in the tree notes.
6	Merchantable Height (4” DOB)	Measure height to point where stem is 4-inch diameter outside bark (DOB), or the point at which the tree forks into branches that are all <4 inches, measured to the nearest 1.0 foot. For trees that taper to a point and then branch out significantly and effectively prevent a reasonable assessment of the 4-inch top, record the height at the point where the stem no longer holds a 4-inch diameter, i.e., the point where the diameter of the largest branch is no longer 4 inches. Since certain species require a value for merchantable height to calculate carbon, merchantable height measurements must be taken for those species to ensure accurate merchantable height values. Note that some species require such heights to be measured from the top of a 1-foot stump. Merchantable height measurements are optional for species not requiring merchantable height to calculate carbon. For projects employing CARIT, merchantable height can be automatically calculated by the tool as a percentage of the total height based on tree species and DBH class if a merchantable height value is not entered for a tree; nevertheless, merchantable heights must be measured for those species requiring such heights to calculate carbon.

Item	Attribute	Description
7	Crown ratio	Make a visual estimate of the ratio of live crown length to total height, as a percentage of the total height, to the nearest 5%. The live crown is based on portion of the tree from the last live foliage at the top of the crown to the visually balanced base of the tree’s crown, following the illustrated guidance in Figure 9.1 from the FIA National Core Field Guide (Version 7.2):  **Figure 9.1. Illustrated guidance for estimating crown ratio.**

<table>
<tr><td rowspan="7">8</td><td rowspan="7">Status</td><td colspan="4">Record the general condition of the tree as either live or dead. For dead trees, additionally identify the decay status. The following table outlines the status categories that are required by CARIT, along with descriptions of each (Burrill et al. 2017) and associated density reduction factors (Harmon et al. 2011):</td></tr>
<tr><th>Status</th><th>Description</th><th colspan="2">Density Reduction Factor</th></tr>
<tr><td></td><td></td><th>Softwoods</th><th>Hardwoods</th></tr>
<tr><td>Live/Recent dead</td><td>Live, or recently dead with all limbs and branches are present; the top of the crown is still present; all bark remains; sapwood is intact with minimal decay; heartwood is sound and hard.</td><td>1.0</td><td>1.0</td></tr>
<tr><td>Snag, few limbs</td><td>There are few limbs and no fine branches; the top may be broken; a variable amount of bark remains; sapwood is sloughing with advanced decay; heartwood is sound at base but beginning to decay in the outer part of the upper bole.</td><td>1.0</td><td>0.80</td></tr>
<tr><td>Snag, limb stubs</td><td>Only limb stubs exist; the top is broken; a variable amount of bark remains; sapwood is sloughing; heartwood has advanced decay in upper bole and is beginning at the base.</td><td>0.92</td><td>0.54</td></tr>
<tr><td>Snag, few stubs</td><td>Few or no limb stubs remain; the top is broken; a variable amount of bark remains; sapwood is sloughing; heartwood has advanced decay at the base and is sloughing in the upper bole.</td><td>0.55</td><td>0.43</td></tr>
<tr><td>9</td><td>Defect</td><td colspan="4">Both standing live trees and standing dead trees may be missing portions of the tree as the result of physical and biological disturbances. Tree biomass needs to be adjusted for missing parts to produce an improved estimate of the tree’s biomass. The above-ground portion of each tree is divided into thirds (top, middle, bottom), with standardized percentages of the tree’s total biomass assumed to be in each third.

Portion of Tree — Percent of Tree Biomass
Top 1/3 — 10%
Middle 1/3 — 30%
Bottom 1/3 — 60%

For standing dead trees, the original disposition of the tree when it was alive and vigorous must be visually estimated to determine where the top, middle and bottom portions of each tree was.</td></tr>
</table>

		For each portion of the tree, make an ocular estimate of the percentage of biomass remaining to the nearest 10%. Deductions from gross volume are made for anything that reduces the tree's gross biomass, including breakage and cavities. The percentage remaining in each third is then proportionally summed to calculate the net biomass remaining in the tree. Estimates for defect in dead trees are combined with density reduction factors identified under Status data above to estimate the net biomass remaining in each dead tree. These calculations are performed automatically by CARIT.
10	Reference tree distance	For reference trees only, measure the distance, in feet, to the nearest 0.1 foot, from center of tree to plot center.
11	Reference tree azimuth	For reference trees only, measure the direction (azimuth), in degrees, from center of tree to plot center.
12	Notes	Enter any special circumstances or ambiguous situations to help clarify measurements or conditions, including but not limited to: 1. Borderline tree 2. Walkthrough tree (counted twice, per walkthrough method) 3. Notes regarding DBH measurement for unusual trees 4. Site tree 5. Reference tree 6. Total tree height estimated due to leaning tree or missing top

9.3 Example Plot Card

Plot and tree data may be recorded on paper or digitally using handheld computers. Project Operators may use the example data form provided in Appendix D as a template for the development of their own paper plot cards or digital form for use on a handheld computer. The form is also available for download as an Excel file on the Forest Project Protocol section of the Climate Action Reserve's website (http://www.climateactionreserve.org/how/protocols/forest/). The form contains the minimum fields required for compliance with the SIM for use of CARIT.

10 Inventory Schedule

The FPP allows for flexibility in how sampling is conducted over time. Inventory data may be collected according to a variety of potential schedules, including on an annual basis, in a single season, or on a periodic basis. This methodology does not require a specific schedule be followed. However, the discussion in this section is intended to provide Project Operators with insight into some of the advantages and disadvantages of various common approaches. Regardless, an important pair of requirements of the protocol that must be considered when determining the inventory scheduling approach to use is that site visit verifications must occur at least every 6 years and that no plots may exceed 12 years of age. Therefore, Project Operators must ensure that plots do not exceed the maximum allowable age and may wish to tailor their inventory schedule to avoid complications that may arise as the time since each plot was last sampled increases.

This section discusses the processes involved with plot management to ensure the field data represents the inventory in the best way possible. It also addresses issues associated with the initial inventory, updating plots on an annual basis, and when to re-measure plots.

10.1 Initial Inventory

Regardless which approach to inventory scheduling is chosen, an initial inventory must be completed that is representative of the entire Project Area population. In other words, the initial inventory must be a complete inventory that samples the required number of plots to achieve the target statistical confidence. Furthermore, the initial inventory must provide inventory data sufficient to meet the reporting and verification requirements of the protocol, and it will serve as the basis for the development of the project's baseline.

10.1.1 Sample Size Determination

The available set of potential plot locations is based on the 2 chain by 2 chain grid laid over and clipped to the Project Area, as outlined in Section 6.1. Project Operators typically try to balance the goal of achieving the target statistical confidence with the desire to limit inventory costs. Since sampling all plots on the grid is impractical for most projects, the Project Operator may estimate the number of plots to be sampled to achieve the target statistical confidence. Such estimates may be based on prior knowledge of the variability of forest conditions across the Project Area, an initial sample taken on a few plots to better understand the variability, an estimate of variation based on other characteristics, or sample size calculations commonly used for forest sampling. As the forest grows and variability within the project changes over the project lifetime, the number of plots that need to get sampled each period will likely change.

The sample size determined prior to initial sampling may need to be adjusted as data are collected and the actual confidence statistics are calculated. In most cases, the change made during initial inventory sampling would likely be the addition of plots to meet the target confidence statistic. Although removing plots (i.e., not sampling plots) if the target confidence statistic has already been met is possible, it is a less likely outcome and is less practical given the logistics typically involved in sampling efforts.

10.2 Updating the Inventory

Forest inventories are always in flux due to forest growth, harvest, and natural disturbances. Therefore, inventories of carbon pools must either be updated or re-measured at a frequency commensurate with the anticipated or actual changes in the specific carbon pools so that sample plots and forest stratification reflect current conditions. Project Operators must report their estimated carbon stocks on an annual basis. Since it may be infeasible to immediately re-measure all plots following forest growth and disturbances that affect plot measurements, acceptable strategies for updating project inventory estimates are described in this section, regardless of the inventory schedule chosen. Such strategies must adhere to the requirement that plots may not be more than 12 years old.

10.2.1 Updating Based on New Information

Data from any new plots that were sampled or existing plots that were re-sampled in the past year must be incorporated into the project inventory. If a plot is re-measured, the old data must be replaced with the new data in terms of representing the plot's inventory. Plot data is valid for 12 years, at which point the plot must be re-measured. The project inventory therefore must be based on plots sampled within the 12-year period. Project Operators may decide to perform all their inventory sampling in a given year or distribute it throughout the 12-year timeframe, as discussed above.

Project Operators using CARIT will add new plot data to the inventory by entering it directly into the database and attributing the plot data with the current date.

10.2.2 Updating for Forest Growth

Updating plot data for forest growth can be accomplished using growth models or stand table projections that mimic the diameter and height increment of trees in the inventory database. Any plot data that are updated by ‘growing’ the plot data will be used during site visit verifications to compare against verifier’s field measurements using the sequential sampling techniques described in the verification section of the FPP. This provision ensures that plot measurements and update processes are within accuracy thresholds. Any plots sampled during the current Reporting Period and prior to the growing season should be included in growth updates.

CARIT will update the inventory for forest growth by growing plot data using the Forest Service’s Forest Vegetation Simulator (FVS), using the functions provided within the tool. All measured plots are always retained within CARIT.

10.3 Updating for Disturbances (Including Harvest)

Inventory estimates must be updated annually for any disturbance (including timber harvest) that results in an estimated reduction to the reported carbon pools of 0.5 percent or more. As disturbances may be occurring throughout the year, rendering challenges to synchronize plot updates with report generation, up to 5 percent of the total inventory plots used to derive the inventory estimate may be excluded at any one time from use in estimating the inventory until they are updated with re-measured data from field visits. The excluded plots are not subject to verification review. This provides some temporal flexibility in performing plot updates. This provision for such plot exclusion for one Reporting Period, after which the excluded plots must be re-measured.

10.3.1 Stratified Inventories

If harvests and/or natural disturbances in the previous year render the previous stratum assignment of the disturbed area to be no longer representative of current conditions, the area that has been disturbed should be re-stratified with a stratum assignment that reflects the post-disturbance forest condition, following the stratification rules developed for the project. Any plots that existed in the disturbed area must be removed from the set of plots used to estimate the stratum average unless, and until, the affected plots are re-measured. However, as outlined above, no more than 5 percent of the total inventory plots may be excluded at any given time and no individual plots may be excluded for more than one Reporting Period.

10.3.2 Non-Stratified Inventories

For non-stratified inventories, any plots associated with a disturbance shall not be used in the inventory estimate and should be updated with revised measurements as soon as possible. As stated previously, no more than 5 percent of the plots can be removed from calculations in a Reporting Period and no plot can be removed for more than one Reporting Period in a row. Plots can only be removed from calculations due to disturbances.

Estimates from sampled pools must meet a minimum confidence standard of a sampling error of ±20 percent at the 90 percent confidence level. It is acceptable to calculate the descriptive statistics, including the sampling error, using plot data that have been updated to a current date. Discounts for uncertainty are applied to project estimates when the sampling error is below ±5 percent at the 90 percent confidence interval.

10.4 Ongoing Inventory

Numerous scheduling approaches are available to Project Operators after the initial inventory is completed. The following discussion identifies a few common approaches and some of the factors that should be considered when deciding on an ongoing schedule for inventorying the Project Area. Regardless which approach to the ongoing inventory is selected, it is recommended that the Project Operator perform spot-checks on plots occasionally to see how well modeled growth aligns with actual growth occurring in the field. If there is a high degree of alignment between the 'grown' data and remeasured data, the Project Operator might consider extending the time period between re-measurement. If the 'grown' data do not line up well with measured data, Project Operators may choose to revisit plots and re-measure them more frequently.

Regardless which schedule the Project Operator chooses, the inventory must be updated every year using growth projections, even if no disturbances occurred, so that the current conditions may be reported in accordance with annual reporting requirements. Additionally, no plot can go more than 12 years without being re-measured in the field.

10.4.1 Annual Inventory

A common approach to inventory scheduling is to sample a portion of the Project Area each year. If sampling is to be conducted annually based on the maximum plot age requirement of 12 years, 8.33 percent (1/12) of previously sampled plots would be re-sampled each year.

Advantages of this approach are that it spreads out the effort and cost of sampling, allows for continuous updating which may provide more accurate annual estimates between verification cycles, and makes being able to locate existing plots more likely as a part of the 6-year verification schedule that requires a site visit. Disadvantages of this approach are that it requires the annual allocation of resources; and plot data must be updated each year (except those measured that year), which requires additional analyst time.

10.4.2 Periodic Inventory Effort Up to a Maximum of 12 Years

A complete inventory of the required number of plots is conducted every 12 years (or other similarly lengthy period) under this approach. The measured plot data are 'grown' to represent the current conditions on each plot for each Reporting Period. Under this approach, the plot data that are verified rely on modeled projections for the maximum period allowed and are, therefore, vulnerable to increasing uncertainties that come with extending periods of modeling.

This approach represents the most cost-effective strategy if the modeling process for growth closely approximates actual conditions. If actual data vary greatly from modeled data, the project may experience substantially increased costs. Worse, it may not be able to be verified at all. As stated previously, it is recommended that Project Operators randomly check actual plot conditions against modeled conditions to determine the alignment of modeled data with actual data as a method to determine the appropriate length of time between plot re-measurements.

11 Calculation Methodologies

Field data collected using the SIM are ultimately used to calculate on-site carbon stocks in standing live and dead trees on the Project Area, as well as the confidence statistics for the inventory. Such calculations are based on obligatory standards outlined in the Quantification Guidance available on the FPP section of the Reserve's website (http://www.climateactionreserve.org/how/protocols/forest/). Project Operators opting to use

CARIT to develop, maintain, and update their inventory have these calculations performed through an automated process within the tool.

12 Data Management Systems and Data Processing

Data collected in the field should be entered into a database, such as CARIT, for permanent storage. The database should be linked to the model used for growth and yield simulations and/or annual inventory updates, with data formatted accordingly for use by the model. The calculation of volume, biomass and carbon, as discussed in Section 11, should be performed in the database that houses the inventory data.

All inventory data, including carbon calculations and growth and yield simulations, should remain stored on personal computers and backed up to a reliable and secure storage location (physical or online). All data must be maintained for a minimum of 100 years after the final issuance of CRTs from the Reserve, in accordance with record keeping requirements outlined in the FPP. Data used to fulfill reporting requirements for each Reporting Period also should be archived and maintained in its original state for the duration of the record keeping period.

13 Quality Assurance/Quality Control

The ultimate quality control for forest project inventory plots occurs during verification. Verification of inventory plots ensures plot measurements are within narrow bounds of error tolerances. Nevertheless, it is recommended that Project Owners have an internal system of quality control to avoid discovery of plot errors during verification. This section describes an approach that provides an increased level of quality assurance prior to verification activities and can serve to correct errors in the implementation of this inventory methodology before they become systemic.

Check cruising is a common method of implementing quality control practices and is performed to identify and correct errors found in the field. Errors may result from a variety of sources, including misunderstandings related to the implementation of the inventory methodology, problems with measurement equipment, or deficiencies exhibited by individual cruisers. The plots selected for review should be randomly selected and should be stratified by individual cruiser or inventory cruising team. The quality control effort should occur early in the sampling process, or soon after new cruisers become involved in the process, to correct problems before they become costly to correct.

The following approach to quality control is recommended. With a new inventory cruiser or inventory team, or at the initiation of a new project:

1. Randomly select 3-4 plots sampled by cruiser or cruising team once there are more than 10 plots installed.
2. An experienced and trusted cruiser will visit the randomly selected plots and collect independent data. The original data collected by the personnel being inspected should be reviewed on the plot, but only after independent data has been collected.
3. Inspections on the plot are shown in Table 13.1.

Check cruising should be adapted to the skill level and consistency of inventory personnel. If problems are found with specific cruisers, remedies should be applied with ongoing random check cruising to rectify the problems. Check cruising can be discontinued entirely if cruisers have a track record of compliance with measurement and methodological standards.

Table 13.1. Inspections on Plot and Inspection Criteria

Inspection Item	Inspection Criteria	Consequences of Failure to Comply
Plot location	Inspect plot coordinates with GPS unit and compare with coordinates from database. Monumented plot location should be within 10 meters of the coordinates from the database or otherwise explainable.	Greater influence on ability to pass verification ↑
Plot monumentation	Plot has a center post (rebar or other) that is highly visible and firmly installed, such that it cannot be moved without substantial effort.	
Trees within plot	1. All trees included in plot must belong. That is, no tree can be included that is not within the plot radius as measured from the center post to the plot boundary as horizontal distance. Horizontal distance varies depending on the plot size used in the sampling methodology. 2. If a nested plot is used, all trees less than the prescribed DBH threshold for the small plot must be included within the inner plot and must never be included outside of the inner plot. 3. All trees within the plot must be counted. That is, if a tree meets the DBH threshold for the methodology, it must be included if it is within the plot.	
Tree Height	Tree height is within 3 feet of recorded tree height.	
DBH	DBH is within 0.2 inches of recorded DBH.	
Species	Tree species is recorded using the correct species code.	
Plot card	Plot card is discernible and completely filled out.	
Defect	Inspector determination generally in agreement with recorded data.	
Status	Inspector determination generally in agreement with recorded data.	
Crown Ratio	Inspector determination generally in agreement with recorded data.	
Notes	The following features, if present, should be included: ▪ Roads and landings ▪ Water bodies and watercourses ▪ If the plot was on a boundary and the walk-through method used. ▪ Rocky outcrops or meadows ▪ Other unique features present	↓ Less influence on ability to pass verification

14 Inventory Methodology Change Log

Although inventory methodologies established at project initiation are meant to be applied throughout the project lifetime, some unforeseen circumstances may compel the Project Operator to revise the methodology. If the inventory methodology is to be changed after the initial verification of the project, the Project Operator must obtain approval for such changes from the Reserve prior to implementing any changes, as indicated in the FPP. Additionally, the Project Operator must document any revisions to the methodology in a change log that is maintained throughout the project lifetime. The change log must indicate the provision(s) of the methodology being changed, why they are being changed, and how they are being changed.

15 References

Burrill, E. A., Wilson, A. M., Turner, J. A., Pugh, S, A., Menlove, J., Christiansen, G., Conkling, B. L., & David, W. (2017). *The Forest Inventory and Analysis Database: Database description and user guide version 7.2 for Phase 2*. Washington, DC: U.S. Department of Agriculture, Forest Service. Retreived from https://www.fia.fs.fed.us/library/database-documentation/

Ducey, M. J., Gove, J. H., & Valentine, H. T. (2004). A walkthrough solution to the boundary overlap problem. Forest Science, 50(4), 427-435. Retrieved from https://nrs.fs.fed.us/pubs/jrnl/2004/ne_2004_ducey_001.pdf

Harmon, M. E., Woodall, C. W., Fasth, B., Sexton, J., & Yatkov, M. (2011). *Differences between standing and downed dead tree wood density reduction factors: A comparison across decay classes and tree species*. (Res. Pap. NRS-15). Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. https://doi.org/10.2737/NRS-RP-15

U.S. Forest Service. (2017). Forest inventory and analysis national core field guide; volume I: field data collection procedures for Phase 2 plots. Ver. 7.2. Washington, DC: U.S. Department of Agriculture, Forest Service. Retrieved from http://www.fia.fs.fed.us/library/field-guides-methods-proc/

Appendix A: Fixed Plot Radius Slope Correction

For trees on slopes greater than 9 percent (as measured from plot center to the central axis of the sample tree, as opposed to the overall plot slope), the fixed plot radius shall be corrected for the slope percent using the Slope Correction Table below. To determine the plot radius to the sample tree corrected for slope, multiply the plot radius for the plot size stated in the project's inventory methodology by the appropriate slope correction factor.

Percent of Slope	Correction Factor
0 to 9	1.00
10 to 17	1.01
18 to 22	1.02
23 to 26	1.03
27 to 30	1.04
31 to 33	1.05
34 to 36	1.06
37 to 39	1.07
40 to 42	1.08
43 to 44	1.09
45 to 47	1.10
48 to 49	1.11
50 to 51	1.12
52 to 53	1.13
54 to 55	1.14
56 to 57	1.15
58 to 59	1.16
60 to 61	1.17
62 to 63	1.18
64 to 65	1.19
66 to 67	1.20
68 to 69	1.21
70	1.22
71 to 72	1.23
73 to 74	1.24
75	1.25
76 to 77	1.26
78 to 79	1.27
80	1.28
81 to 82	1.29
83	1.30

Percent of Slope	Correction Factor
84 to 85	1.31
86	1.32
87 to 88	1.33
89	1.34
90 to 91	1.35
92	1.36
93 to 94	1.37
95	1.38
96 to 97	1.39
98	1.40
99 to 100	1.41
101	1.42
102	1.43
103 to 104	1.44
105	1.45
106 to 107	1.46
108	1.47
109	1.48
110 to 111	1.49
112	1.50
113	1.51
114 to 115	1.52
116	1.53
117	1.54
118 to 119	1.55
120	1.56
121	1.57
122	1.58
123 to 124	1.59
125	1.60
126	1.61

Percent of Slope	Correction Factor
127 to 128	1.62
129	1.63
130	1.64
131	1.65
132 to 133	1.66
134	1.67
135	1.68
136	1.69
137 to 138	1.70
139	1.71
140	1.72
141	1.73
142 to 143	1.74
144	1.75
145	1.76
146	1.77
147	1.78
148 to 149	1.79
150	1.80

Appendix B: Tree Species Codes

Alphabetic species codes used by the USDA PLANTS database, along with associated common names, scientific names, and FIA species codes, are provided in an Excel file available on the Forest Project Protocol section of the Climate Action Reserve's website (http://www.climateactionreserve.org/how/protocols/forest/). The list is arranged alphabetically by scientific name.

Appendix C: Tree Diameter Measurement Guidance Adapted from USFS FIA Core Field Guide (Version 7.2)

Unless one of the following special situations is encountered, measure DBH at 4.5 feet above the ground line on the uphill side of the tree. For trees requiring DRC measurements, measure the diameter at the ground line or at the stem root collar, whichever is higher.

Special DBH situations:

1. Forked tree: To qualify as a fork, the stem in question must be at least 1/3 the diameter of the main stem and must branch out from the main stem at an angle of 45 degrees or less. Forks originate at the point on the bole where the piths intersect. Forked trees are handled differently depending on whether the fork originates below 1.0 foot, between 1.0 and 4.5 feet, or above 4.5 feet.

   Trees forked below 1.0 foot: Trees forked below 1.0 foot are treated as distinctly separate trees (fig. 23). Distances and azimuths are measured individually to the center of each stem where it splits from the stump (fig. 26 A-C). DBH is measured for each stem at 4.5 feet above the ground. When stems originate from pith intersections below 1 foot, it is possible for some stems to be within the limiting distance of the microplot or subplot, and others to be beyond the limiting distance. If stems originating from forks that occur below 1.0 foot fork again between 1.0 and 4.5 feet (fig. 26-E), the rules in the next paragraph apply.

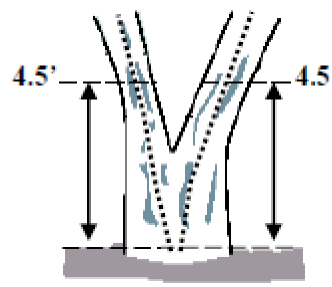


Figure 23. Forked below 1.0 ft.

   Trees forked between 1.0 foot and 4.5 feet: Trees forked between 1.0 foot and 4.5 feet are also counted as separate trees (fig. 24), but only one distance and azimuth (to the central stump) is recorded for each stem (fig. 26 D-F). Although a single azimuth and distance applies to all, multiple stems should be recorded as they occur in clockwise order (from front to back when one stem is directly in front of another). The DBH of each fork is measured at a point 3.5 feet above the pith intersection. When forks originate from pith intersections between 1.0 and 4.5 feet, the limiting distance is the same for all forks--they are either all on, or all off the plot.

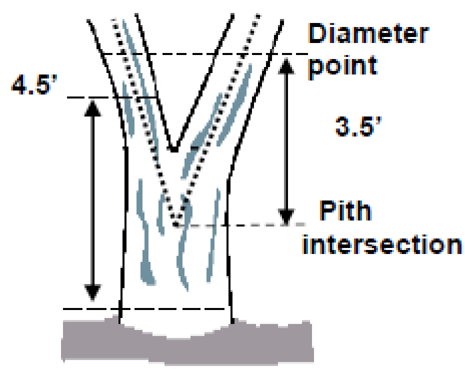


Figure 24. Forked between 1.0-4.5 ft.

   Multiple forks are possible if they all originate from approximately the same point on the main stem. In such cases, measure DBH on all stems at 3.5 feet above the common pith intersection (fig. 26-G).

Once a stem is tallied as a fork that originated from a pith intersection between 1.0 and 4.5 feet, do not recognize any additional forks that may occur on that stem. Measure the diameter of such stems just below the base of stem separation as shown in figures 26-E and 26-F (i.e., do not move the point of diameter the entire 3.5 feet above the first fork).

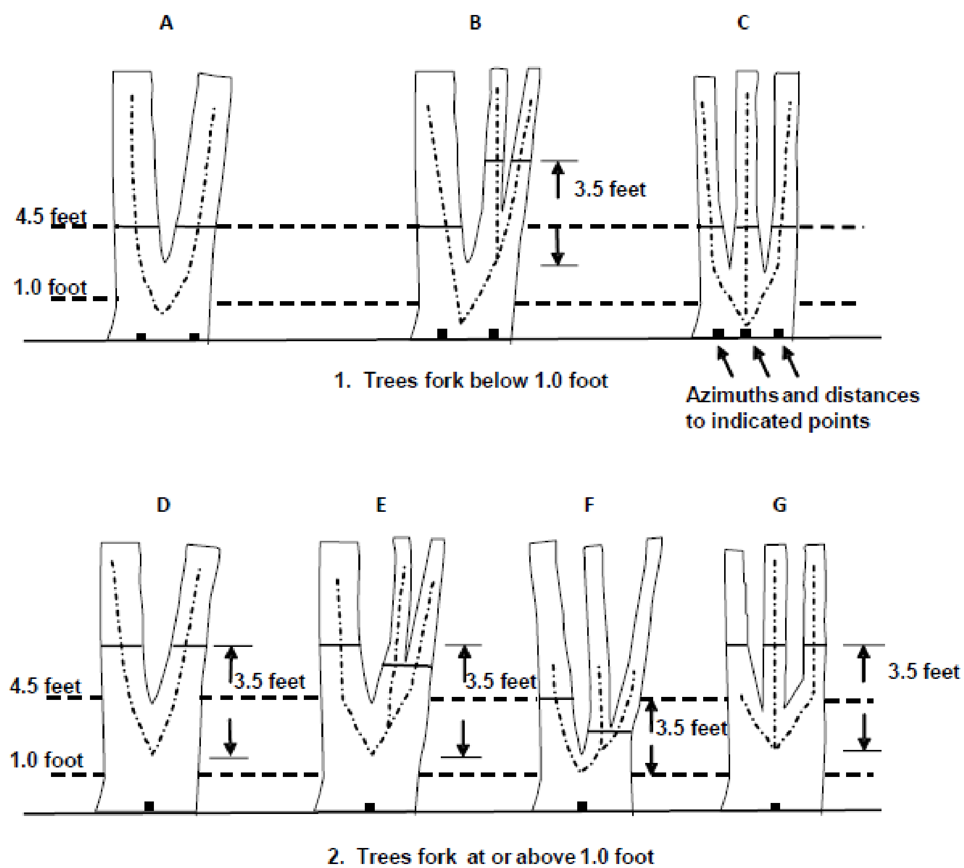


Figure 26. Summary of where to measure DBH, distance, and azimuth on forked trees.

Trees forked at or above 4.5 feet: Trees forked at or above 4.5 feet count as one single tree (fig. 25). If a fork occurs at or immediately above 4.5 feet, measure diameter below the fork just beneath any swelling that would inflate DBH.

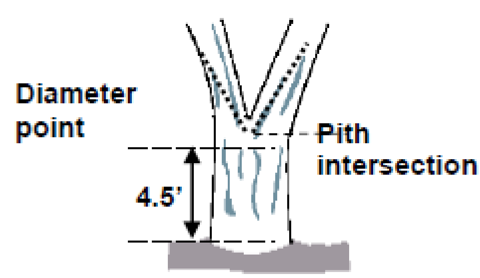


Figure 25. One tree.

2. Stump sprouts: Stump sprouts originate between ground level and 4.5 feet on the boles of trees that have died or been cut. Stump sprouts are handled the same as forked trees, with the

exception that stump sprouts are not required to be 1/3 the diameter of the dead bole. Stump sprouts originating below 1.0 foot are measured at 4.5 feet from ground line. Stump sprouts originating between 1.0 foot and 4.5 feet are measured at 3.5 feet above their point of occurrence. As with forks, rules for measuring distance and azimuth depend on whether the sprouts originate above or below 1.0 foot. For multi-stemmed woodland species, treat all new sprouts as part of the same new tree.

3. <u>Tree with butt-swell or bottleneck:</u> Measure these trees 1.5 feet above the end of the swell or bottleneck if the swell or bottleneck extends 3.0 feet or more above the ground (fig. 27). Swells or bottlenecks extending to less than 3.0 feet above the ground do not affect DBH measurement.

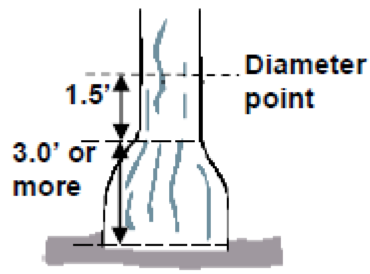


Figure 27. Bottleneck tree.

4. <u>Tree with irregularities at DBH:</u> On trees with swellings (fig. 28), bumps, depressions, and branches (fig. 29) at DBH, diameter will be measured immediately above the irregularity at the place it ceases to affect normal stem form. If point of diameter measurement above the irregularity cannot be reached safely, estimate the diameter and explain the situation in the notes.

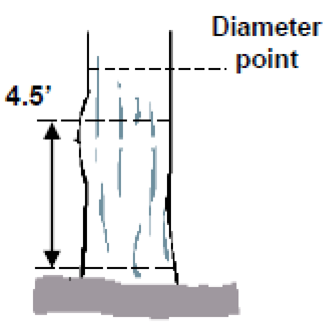


Figure 28. Tree with swelling.

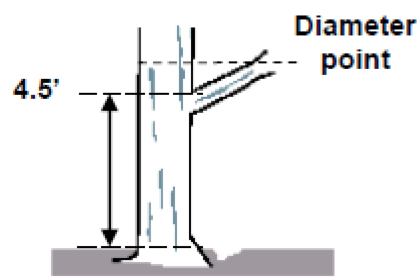


Figure 29. Tree with branch.

5. <u>Tree on slope:</u> Measure diameter at 4.5 feet from the ground along the bole on the uphill side of the tree (fig. 30).

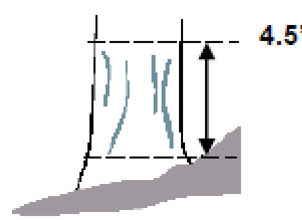


Figure 30. Tree on a slope.

6. Leaning tree: For any tree with lower third of bole leaning more than 10% from vertical, measure diameter at 4.5 feet from the ground along the bole. The 4.5-foot distance is measured along the underside face of the bole (fig. 31).

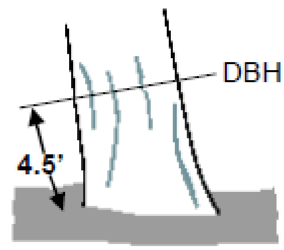


Figure 31. Leaning tree.

7. Turpentine tree: On trees with turpentine face extending above 4.5 feet, estimate the diameter at 10.0 feet above the ground and multiply by 1.1 to estimate DBH outside bark.

8. Independent trees that grow together: If two or more independent stems have grown together at or above the point of DBH, continue to treat them as separate trees. Estimate the diameter of each and explain the situation in the notes.

9. Missing wood or bark: Do not reconstruct the DBH of a tree that is missing wood or bark at the point of measurement. Record the diameter, to the nearest 0.1 inch, of the wood and bark that is still attached to the tree (fig. 32). If a tree has a localized abnormality (gouge, depression, etc.) at the point of DBH, apply the procedure described for trees with irregularities at DBH (figs. 28 and 29).

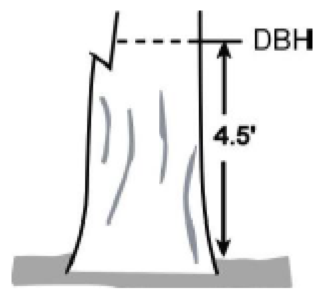


Figure 32. Tree with part of stem missing.

10. Live windthrown tree: Measure from the top of the root collar along the length to 4.5 feet (fig. 33).

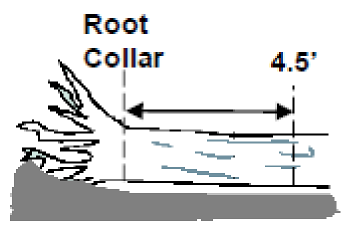


Figure 33. Tree on the ground.

11. <u>Down live tree with tree-form branches growing vertical from main bole:</u> When a down live tree, touching the ground, has vertical (less than 45 degrees from vertical) tree-like branches coming off the main bole, first determine whether or not the pith of the main bole (averaged along the first log of the tree) is above or below the duff layer.
    - If the pith of the main bole is above the duff layer, use the same forking rules specified for a forked tree, and take all measurements accordingly (fig. 34).
    - If the pith intersection of the main down bole and vertical tree-like branch occurs below 4.5 feet from the stump along the main bole, treat that branch as a separate tree, and measure DBH 3.5 feet above the pith intersection for both the main bole and the tree-like branch.

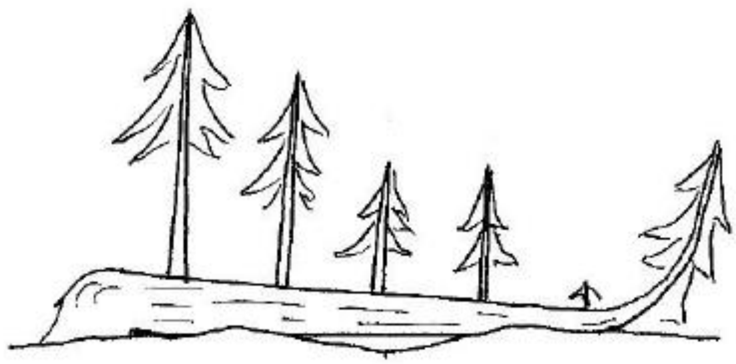


Figure 34. Down tree above duff.

    - If the intersection between the main down bole and the tree-like branch occurs beyond the 4.5 feet point from the stump along the main bole, treat that branch as part of the main down bole.
    - If the pith of main tree bole is below the duff layer, ignore the main bole, and treat each tree-like branch as a separate tree; take DBH and length measurements from the ground, not necessarily from the top of the down bole (fig. 35). However, if the top of the main tree bole curves out of the ground towards a vertical angle, treat that portion of that top as an individual tree originating where the pith leaves the duff layer.

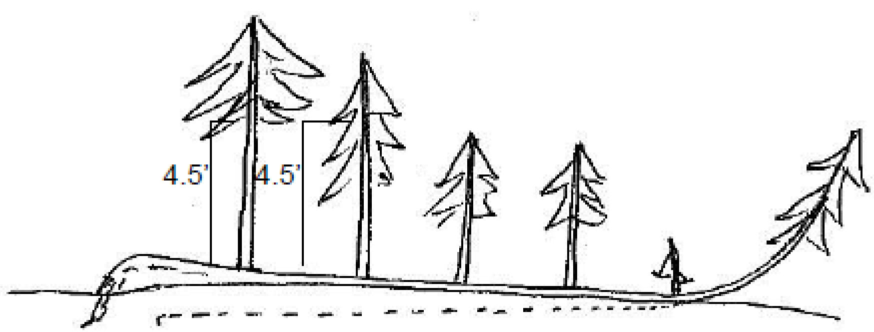


Figure 35. Down tree below duff.

12. Tree with curved bole (pistol butt tree): Measure along the bole on the uphill side (upper surface) of the tree (fig. 36).

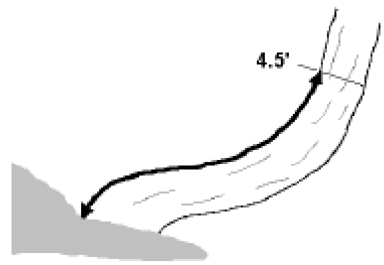
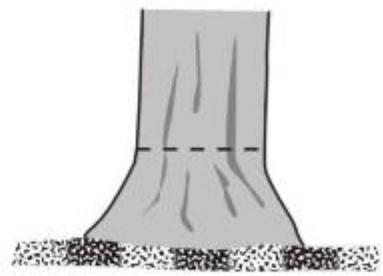


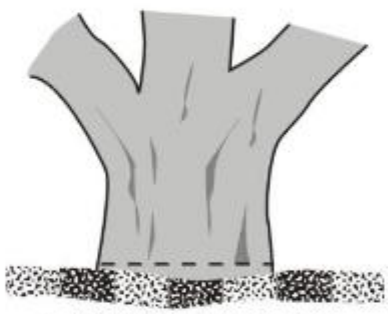
Figure 36. Tree with curved bole (pistol butt tree).

Use the following illustrated guidance for trees requiring DRC measurements:

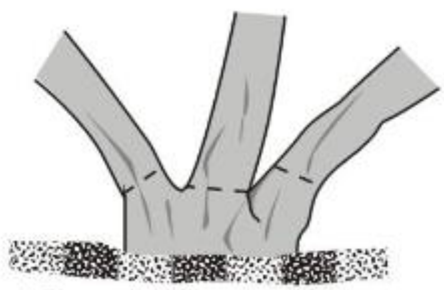
1. Measure at ground line when reasonable.



2. Measure above root collar.

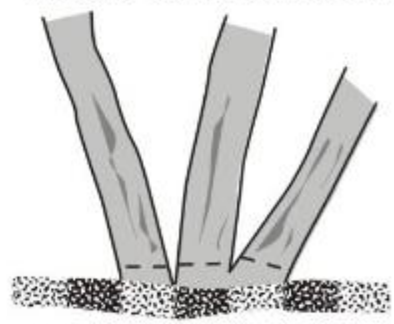


3. Multistemmed above diameter.



4. Excessive diameter below stems. Measure stems. Compute DRC.

5. Ignore cut/missing stem(s). Compute DRC.



6. Multistemmed at or below ground. Compute DRC.

Appendix D: Example Plot Card

The following form may be used as a template for the development of paper plot cards or digital forms for use on a handheld computer. The template is also available for download as an Excel file on the Forest Project Protocol section of the Climate Action Reserve's website (http://www.climateactionreserve.org/how/protocols/forest/).

Date of visit	____________	Location with GPS reception near plot center			#1	#2
Plot number	____________	Latitude	________________	Ref tree distance	_______	_______
Stratum	____________	Longitude	________________	Ref tree azimuth	_______	_______
Cruiser(s)	____________	Distance to plot center	________________	Site tree age	_______	
Slope	____________	Azimuth to plot center	________________	Site tree species	_______	
Aspect	____________	Plot type	________________			
Notes:						

Tree #	Species	DBH (0.1")	Height, total (1')	Height, merch (1')	Crown ratio (5%)	Status code (1-5)	Defect (nearest 10%)			# of stems (if >1)	Notes
							Top 1/3	Middle 1/3	Bottom 1/3		