Quantification Guidance for Use with RGGI U.S. Forest Offset Projects

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This document provides additional quantification guidance to the RGGI U.S. Forest Projects Offset Protocol (protocol). The additional guidance represents best management practices for Project Sponsors and Verifiers in developing project estimates and forecasting baselines.

CONTENTS

1 Reporting Requirements for Forest Carbon Pools 2
2 Guidance for Estimating Carbon in Forest Carbon Pools 2
2.1 Use of Sampled Data 2
2.2 Updating Forest Inventories 2
2.2.1 Updating for Forest Growth 2
2.2.2 Updating for Disturbances (Including Harvest) 3
2.3 Requirements for Estimating Carbon in Standing Live and Dead Trees 3
2.4 Use of Regression Equations 5
2.5 Forest Vegetation Stratification 5
2.6 Quantification of Carbon in Live Trees from Project Data 5
2.7 Adjustments to Standing Live and Standing Dead Trees for Missing Volume and Decay 6
2.8 Recommendations for Estimating Lying Dead Wood Carbon 8
2.9 Onsite Carbon Stocks Affected by Site Preparation Activities with Reforestation Projects 10
2.10 Total Onsite Carbon Stocks and Calculating the Confidence Deduction 11
2.10.1 Applying a Confidence Deduction to Sampled Estimates 11
2.11 Requirements for Calculating Carbon in Harvested Wood Products 12
3 Modeling Carbon Stocks 13
3.1 Models and their Eligibility for Use with Forest Projects 13
3.2 Using Models to Forecast Carbon Stocks 15
3.3 Modeling Requirements 15

1 Reporting Requirements for Forest Carbon Pools

Onsite forest carbon pools are broadly grouped into living biomass, dead biomass, and soils. Living biomass includes biomass in live trees and shrubs & herbaceous understory (live non-tree biomass). Onsite dead biomass includes biomass in dead trees, lying dead wood, and litter. Offsite dead biomass includes harvested wood products.

For standardized reporting under the protocol, all estimates of forest carbon stocks should be provided in terms of metric tons of CO_2 equivalent (CO_2e) on a project and a per acre basis. Unless otherwise required in the referenced biomass equations, the following conversion formulae are recommended:

Base Unit	Conversion		Final Unit
Biomass	0.5 **x** biomass	=	Carbon
Carbon	3.67 **x** carbon	=	CO_2e
Tons	0.90718474 **x** tons	=	Metric tons
Hectares	0.404686 **x** hectares	=	Acres

2 Guidance for Estimating Carbon in Forest Carbon Pools

This section describes requirements for the development of values for the forest carbon pools described in Section 1. Project Sponsors must include an inventory methodology in the Monitoring and Verification Plan. The inventory methodology should include the required provisions identified in this section.

2.1 Use of Sampled Data

All inventory methodologies should be based on randomized or systematic sampling and include the minimum quality parameters described in this section for each carbon pool. Inventory methodologies should describe the process for locating sample plots. Sample plot locations may be monumented in such a way to assist in relocating them for quantification and verification purposes. Plot monument strategies that incorporate Global Positioning Systems (GPS) along with additional navigational strategies at close range to plot centers (in order to direct verifiers to the precise plot location) that are resistant to weather, wildlife, and other environmental factors, can substantially reduce verification costs. Project Sponsors are advised to consider the verification guidance (Section 10 of the protocol) associated with verification of sampled carbon pools (in particular, the sequential sampling guidance) prior to settling on a strategy to monument plot locations.

2.2 Updating Forest Inventories

Forest inventories are always in flux due to forest growth, harvest, and natural disturbances. Therefore, inventories of carbon pools should 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 Sponsors must report their estimated carbon stocks on an annual basis. Since it is 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.

2.2.1 Updating for Forest Growth

Updating plot data for forest growth can be accomplished through the use of growth models or stand table projections that mimic the diameter and height increment of trees in the inventory database. Since growth models do not typically 'grow' trees on an annual basis, an analysis of the average annual increment of diameters and heights should be conducted and added to the previous year's inventory tree lists. Any plot data that are updated to reflect current conditions with the use of predicted increments of height and diameter data will be used during site visit verifications to compare against verifier's field measurements using the sequential sampling techniques described in the Section 10 of the protocol. This provision ensures that plot measurements and update processes are within accuracy thresholds.

2.2.2 Updating for Disturbances (Including Harvest)

Inventory estimates should be updated annually for any disturbance (including harvest disturbance) that results in an estimated reduction to the reported carbon pools of 0.5 percent or more. If the inventory is stratified, the area that has been disturbed can simply be re-stratified with a stratum that reflects the post-disturbance forest condition, following the stratification rules developed for the project. Any plots that existed in the disturbed area should be removed from the set of plots used to estimate the stratum average unless, and until, the affected plots are re-measured. Verification of stratified inventories should ensure that the area disturbed is accurately characterized in the inventory GIS system and that the assigned stratum reflects the forest condition.

For non-stratified inventories, an estimated tree list that represents the post-disturbance condition of the forest should be assigned to any plots affected by the disturbance. The tree list should be carefully selected to not overstate the carbon pools present. Site verification of post-disturbance plots will evaluate whether the tree list assigned is appropriate for the post-disturbance condition. No more than 10 percent of the project's area may be represented through estimated plots without increased verification scrutiny during a site visit. Specifically, where more than 10 percent of the project's area is based on estimated tree lists assigned to plots, verification using sequential sampling techniques shall include all plots (including estimated plots) in the sequential sampling comparison between Project Sponsor estimates and verifier estimates.

Plots that are estimated shall not be used in the calculations for sampling error. Estimates from sampled pools should meet a minimum confidence standard of +/- 20 percent at the 90 percent confidence interval. It is acceptable to calculate the descriptive statistics, including confidence intervals, using plot data that have been updated to a current date. Discounts for uncertainty are applied to project estimates when confidence standards are below +/- 5 percent at the 90 percent confidence interval. This is described in greater detail below.

2.3 Requirements for Estimating Carbon in Standing Live and Dead Trees

It is required that both standing live and standing dead trees be sampled. It is acceptable, but not required, to combine standing live and dead trees during sampling such that descriptive statistics, including confidence statistics, address the combined pools. Whether combined or not, tree data should be coded so that mean estimates can be interpreted independently for standing live and standing dead pools to allow monitoring of standing dead trees with respect to requirements in the Natural Forest Management section (Section 3.8.2) of the protocol.

Inventory methodologies should include a description of how the sampled data will be archived and the analytical tools that will be included in the analysis of carbon stocks. The tree lists that are developed from inventory sampling and used to expand inventory estimates to the project level should be available for verification review. It is acceptable for the tree list to be presented and reviewed in an electronic format, such as in a database or spreadsheet application. Table

2.1 displays suggestions that all project inventory methodologies should include for standing live and dead trees.

Table 2.1. Requirements for Sampling Standing Live and Standing Dead Trees

Species	1. All trees sampled should include a species identifier. The inventory methodology should provide a crosswalk between any codes used to identify a species and the species name the codes represent. 2. Since all trees contain carbon, the inventory methodology should indicate that the sample methodology will include all species present within the project area (not just the merchantable trees, for example).
Diameter at Breast Height (DBH) Measurements	1. Inventory estimates should include all trees 5 inches DBH and larger. It is acceptable that inventory methodologies include trees with DBH less than 5 inches. 2. The location of the measurement of DBH should follow U.S. FIA sampling guidelines. 3. Measurement precision should be no greater than the nearest inch.
Height	1. Inventory methodologies should describe whether all trees on sample plots are measured for height or whether a subset of the sample plot heights is measured and regression estimators are developed for unmeasured heights. 2. Inventory methodology should describe whether height measurements describe the tree's total height or some other top height measurement. Regression estimators, or published form equations, may also be used to estimate top heights from a partial height or vice versa. Where regression estimators are used for tree heights, the inventory methodology should describe the populations from which the regression estimators were acquired. 3. The sampling precision for tree heights (when measured) should be stated in the inventory methodology. Stated acceptable precision for measured heights should not be greater than +/- 10 feet. 4. The inventory methodology should include a description of the maximum angle accepted for measuring tree heights. The stated maximum acceptable slope to the measured height should not exceed 120 percent.
Weight (Plot Area and Forest Strata)	1. All methodologies should describe the sample plot areas used to determine which trees are included for measurement. 2. All tree lists should include a field(s) that displays the weighting of each sampled tree in order to expand the sampled tree to a per acre value. 3. Where inventories are stratified, the governing rules for stratification and stratification methodology should be described. The process for updating forest strata should be described. 4. Where inventories are stratified, stratum areas should be provided at verification with maps and tabular outputs.
Status	1. Each sampled tree should be identified as live or dead. 2. Dead trees should be coded with the decay status so density adjustments can be made. Decay class descriptions and density adjustments are provided below.

Biomass Equations	1. All projects should calculate the biomass in each tree using the biomass equations provided by RGGI (can be found on www.rggi.org). 2. The project's inventory methodology should include a list of the equations and cite the version of the RGGI's equation file from which they were copied.
Deductions for Missing Biomass	1. Both live and dead trees may have cavities, broken tops or other deformities that reduce the biomass in the trees. Therefore, the inventory methodology should include a description of how deductions are estimated to account for missing biomass. RGGI has provided guidance below that is acceptable. Alternative methods that address deductions for missing biomass are subject to approval by RGGI.

Sampling methodologies and measurement standards should be consistent throughout the duration of the forest project. If new sampling methodologies are incorporated during the project life, they should be approved by RGGI. Sampling methodologies and measurement standards will be evaluated for their statistical validity. Additionally, uncertainties in estimates associated with modifications to sampling methodologies may require reconciliation to project data and/or baseline estimates and shall be conducted at the RGGI's sole discretion. The application of a revised sampling methodology can only occur as part of a site visit verification.

2.4 Use of Regression Equations

It is acceptable to develop carbon inventories using regression estimators to estimate tree heights. Project Sponsors should keep in mind that plots or (sub) populations will be randomly selected for verification and that regression estimators should be used where a high level of certainty can be developed from the estimators. Failure to do so will result in increased effort and cost to meet the standards of verification.

2.5 Forest Vegetation Stratification

Stratification is not required, but it may simplify verification and possibly lower the costs of verification. Where forest vegetation is stratified, inventory methodologies should describe the guidelines used for stratification. Traditional stratification decisions are usually based on species composition, forest stem size (DBH or height), and density. It is important that the stratification be relevant to sampling forest carbon. The minimum polygon size to which the stratification guidelines apply should be included in the methodology. A map of current forest strata should be included in the project documentation. The methodology should also include the process guidelines for updating forest strata for disturbance and growth events.

2.6 Quantification of Carbon in Live Trees from Project Data

All projects should use the appropriate biomass equations for the assessment areas the project is located in. The required biomass equations are found on www.rggi.org. The calculation of CO_2e for each tree should be conducted in a manner that provides project estimates for:

- Whole tree biomass (roots, stump, bark, bole, top, and branches). Whole tree estimates are used to provide project totals and estimates of emissions associated with harvest activities.
- Bole biomass. The bole should be calculated when the bole portion of harvested trees are delivered to manufacturing facilities for processing. It is used as the basis for determining carbon persisting in long-term wood products.
- Above-ground portion (stump, bark, bole, top, and branches) used to compare project data to common practice statistics for Improved Forest Management projects.

- Bole portion, for inclusion in calculations of carbon stored in harvested wood products.

Projects outside of California, Oregon, Washington, Alaska, and Hawaii use estimators for non-bole portions of the tree referred to as the Component Ratio Method (CRM). The CRM shall be used to compute the various portions of the tree mentioned above. Guidance for the use of the CRM is provided on www.rggi.org.

Projects in California, Oregon, Washington, Alaska, and Hawaii shall use the biomass equations provided on www.rggi.org to calculate the above-ground portion of the trees. The Cairn's equation (Cairns, Brown, Helmer, & Baumgardner, 1997) shall be used to calculate CO_2e in the below-ground portion of the trees. The Cairn's equation is:

BBD = exp[-0.7747 + 0.8836 x ln(ABD)]

$$BBD = \exp[-0.7747 + 0.8836 \times \ln(ABD)]$$

Where,

			Units
BBD	=	Below-ground biomass density of standing live trees	metric tons/hectare
ABD	=	Above-ground biomass density of standing live trees	metric tons/hectare

This estimate should be converted from biomass in metric tons per hectare to CO_2e in metric tons per acre using the conversions identified in Section 1 of this guidance.

2.7 Adjustments to Standing Live and Standing Dead Trees for Missing Volume and Decay

Both standing dead trees and standing live 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. Calculating CO_2e in standing dead trees raises additional challenges since they may be in stages of decay such that density equations in standard biomass equations for live trees do not provide an accurate estimate. The guidance in this section provides a standardized method to account for biomass adjustments.

The first step is to estimate the gross biomass in the tree as if it were whole, using the biomass equations (the first step in the biomass and carbon calculations) provided on www.rggi.org. The tree's biomass is then adjusted based on the tree's 'net' biomass and adjusted density estimates for standing dead trees. To standardize, the tree is divided into four parts: top, middle, bottom (visually estimating the original disposition of the above-ground portion of the tree when it was alive and vigorous), and the below-ground portion. The below-ground portion should be calculated as it would for a normal, healthy tree, using the Cairn's equation where the regional biomass equations are used instead of the CRM. It is assumed that the below-ground portion is intact and complete. The standardized percentages assumed to be in each portion of the tree are shown in Table 2.2.

Table 2.2. Assumed Percentages of Biomass in Each Portion of the Tree

Tree Portion	Percent of Tree Biomass
Top 1/3	10%
Middle 1/3	25%
Bottom 1/3	65%

An ocular estimate is made of the portion remaining in each section of the tree during field sampling. 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 summed to calculate the net biomass remaining in the tree.

The tree's density should be adjusted to account for the varying states of decay in the remaining portion of the tree. Because standing dead wood does not have the same density as a live tree, a density reduction should be applied. Standing dead wood may fall into five decay classes, which should be recorded during the field sampling. The five decay classes, described in **Error! eference source not found.**Table 2.3, are qualitative, based on the physical characteristics of the dead tree (USDA 2007, Woundenberg et al., 2010).

Table 2.3. Decay Classes

Decay Class	Description of Condition of Standing Dead Wood
1	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.
2	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.
3	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.
4	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.
5	No evidence of branches remains; the top is broken; less than 20 percent of the bark remains; sapwood is gone; heartwood is sloughing throughout.

The density identified for each species in the biomass equations posted on www.rggi.org should be modified for decay classes 2 to 5 using the reduction factors displayed in Table 2.4,[1] which are multiplied by the densities provided in the biomass equations.

Table 2.4. Average Density Reduction Factors for Standing Dead Wood for Hardwoods and Softwoods by Decay Class

Softwoods		Hardwoods	
Decay Class	**Reduction Factor**	**Decay Class**	**Reduction Factor**
2	1.0	2	0.8
3	0.92	3	0.54
4	0.55	4	0.43
5	0.29	5	0.22

An example of field data that has all of the required elements for calculating the standing dead tree's CO_2e is shown in Table 2.5.

[1] Harmon et al, 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. 40 p.

Table 2.5. Example: Data Attributes Needed to Calculate CO_2e in Standing Dead Trees

Tree Number	Species (type)	Status	DBH (inches)	Height* (feet)	Percent Remaining			Decay Class
					Top 1/3 of Tree	Middle 1/3 of Tree	Bottom 1/3 of Tree	
1	Hardwood	Dead	16	95	0%	50%	100%	3

*Estimated height prior to death

The density of the tree should be adjusted based on its decay class. The first step is to calculate the tree's biomass as if the tree were a normal tree to determine the tree's gross biomass. Net biomass is determined by multiplying the gross biomass of the tree by the reduction factor displayed in Table 2.4. An example is provided in Table 2.6.

Table 2.6. Example: Adjusting Biomass Calculation for Decay Using Density Adjustment Factors

Tree Gross Biomass	Density Reduction Based on Decay	Net Biomass
(metric tons CO_2e) (Assumed)	(from Table 2.4 for a hardwood with a decay class '3')	(metric tons CO_2e) (Assuming tree is whole)
0.100	0.54	0.054

As an example of the application of the biomass deductions for missing sections of the tree, using the data from Table 2.5 above, a tree (assuming normal form) with a net biomass of 0.054 metric tons CO_2e would be further adjusted to a net biomass for the missing portions of the tree as shown in Table 2.7.

Table 2.7. Example: Calculating Net Biomass in a Tree

Tree Portion	Percent of Tree Biomass	Gross Biomass	Percent Remaining in Tree	Net Biomass
	(from Table 2.2)	(metric tons CO_2e) Percent of tree biomass **x** tree biomass adjusted for density (Table 2.6)	(from example in Table 2.5)	(metric tons CO_2e) Percent remaining in tree **x** gross biomass
Top 1/3	10%	10% **x** 0.054 **=** 0.0054	0%	0.00000
Middle 1/3	25%	25% **x** 0.054 **=** 0.0135	50%	0.00675
Bottom 1/3	65%	65% **x** 0.054 **=** 0.0351	100%	0.0351
Total Biomass		0.054		0.04185

2.8 Recommendations for Estimating Lying Dead Wood Carbon

All projects shall either maintain an inventory of lying dead wood for the project area or monitor harvested areas according to the guidance in this section to ensure the project meets the conditions identified in Section 3.8.2 of the protocol. Lying dead wood is not eligible for crediting due to the high variability associated with estimating lying dead wood, resulting in estimates with unacceptable levels of uncertainty for crediting. Project Sponsors are urged to include the status of lying dead wood with each monitoring report.

Project Sponsors that choose to meet the monitoring recommendation by maintaining an inventory of lying dead wood should meet the following requirements:

1. Inventory plots or transects used to provide the lying dead wood estimate should be no older than 12 years.

Data collected for lying dead wood should include the estimated species, adequate data to estimate volume, and decay class, as defined by

2. Table 2.8 below, to estimate the density of the piece of lying dead wood to determine biomass.
3. The sampling methodology should be included in the project documentation. RGGI is not prescriptive with regards to the sampling design, other than adhering to general statistical principles of randomness. Fixed area plots and line transects, among other sampling methodologies, are acceptable.
4. The inventory sampling confidence in the estimate of lying dead wood should be at +/- 30 percent at 1 standard error.

Project Sponsors that choose to meet the monitoring requirement through monitoring of harvested areas should meet the following requirements:

1. A harvested area is any area where commercial removal of forest vegetation has occurred.
2. A map of all areas harvested during the last reporting period should be submitted with the annual monitoring report and should include the harvest date.
3. All harvested areas should be monitored within one year of the harvest date.
4. Fixed area strips shall be randomly located on compass bearings chosen by the Project Sponsor (but maintained consistent within each harvest area). A recommended width of the fixed area strip is 66 feet (1 chain), which will require monitoring in each of the 33 foot areas on either side of the center line. Ten square chains equals one acre. Project Sponsors can determine the width of the strip that best suits the vegetation conditions present in the harvested area.
5. A map shall be produced that displays the location of the fixed area strips on the harvested areas. The width of the strip shall be documented for each strip.
6. The minimum area monitored shall be 5 percent of each harvested area.

Data collected within the fixed area strip should include the estimated length of the piece of lying dead wood, the average diameter of the lying dead wood, the estimated species, and the decay class as defined by

7. Table 2.8 below.

Lying dead wood density should be adjusted to account for the state of decay. Because lying dead wood does not have the same density as a live tree, a density reduction should be applied. Lying dead wood may fall into five decay classes, which should be recorded during the field sampling. The five decay classes are qualitative based on the physical characteristics of the dead tree (USDA 2007, Woundenberg et al., 2010).

Table 2.8. Decay Class Descriptions of Lying Dead Wood

Decay Class	Description of Condition of Lying Dead Wood
1	Sound, freshly fallen, intact logs with no rot; no conks present indicating a lack of decay; original color of wood; no invading roots; fine twigs attached with tight bark.

Decay Class	Description of Condition of Lying Dead Wood
2	Sound log sapwood partly soft but cannot be pulled apart by hand; original color of wood; no invading roots; many fine twigs are gone and remaining fine twigs have peeling bark.
3	Heartwood is still sound with piece supporting its own weight; sapwood can be pulled apart by hand or is missing; wood color is reddish-brown or original color; roots may be invading sapwood; only branch stubs are remaining which cannot be pulled out of log.
4	Heartwood is rotten with piece unable to support own weight; rotten portions of piece are soft and/or blocky in appearance; a metal pin can be pushed into heartwood; wood color is reddish or light brown; invading roots may be found throughout the log; branch stubs can be pulled out.
5	There is no remaining structural integrity to the piece with a lack of circular shape as rot spreads out across ground; rotten texture is soft and can become powder when dry; wood color is red-brown to dark brown; invading roots are present throughout; branch stubs and pitch pockets have usually rotten down.

The density identified for each species in the biomass equations posted on www.rggi.org should be modified for decay classes 2 to 5 using the reduction factors displayed in Table 2.9,[2] which are multiplied by the densities provided in the biomass equations.

Table 2.9. Average Density Reduction Factors for Lying Dead Wood for Hardwoods and Softwoods by Decay Class

Softwoods		Hardwoods	
Decay Class	**Reduction Factor**	**Decay Class**	**Reduction Factor**
2	0.87	2	0.74
3	0.70	3	0.51
4	0.40	4	0.29
5	0.29	5	0.22

An adjusted density coefficient for the downed logs is calculated by multiplying the density coefficient provided with the biomass equations on www.rggi.org by the reduction value in the table above. The adjusted density value is multiplied by the volume estimate in the lying dead wood to determine the biomass.

2.9 Onsite Carbon Stocks Affected by Site Preparation Activities with Reforestation Projects

The removal of standing dead trees, brush, and downed logs associated with Reforestation projects may constitute a significant quantity of emissions compared to the project benefits in the short term. Therefore, Reforestation projects should estimate the biological emissions associated with site preparation activities prior to planting trees.

[2] Harmon et al, 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. 40 p.

For carbon pools that will be affected by site preparation, an inventory of the pools that will be affected should be conducted prior to any site preparation activities. For those carbon pools that are affected by site preparation, Project Sponsors should provide an estimate of initial carbon stocks using one of the following alternatives:

- Measuring carbon stocks using 20 randomly placed sample plots located in the portion of the project area containing the greatest amount of biomass in the pool or pools that will be affected. The portion of the area sampled shall be calculated. The estimate derived on a per acre basis shall be applied to the balance of the project area.
- Stratifying (classifying) the project area into similar densities and measuring stocks within the affected carbon pools using 20 randomly located sample plots per density class.
- Measuring the affected carbon stocks based on a systematic grid system across the project area.

2.10 Total Onsite Carbon Stocks and Calculating the Confidence Deduction

Annual reporting is conducted by summing the carbon stocks present at the end of the reporting period in all of the relevant carbon sources, sinks, and reservoirs for the project. Certain reported pools are sampled and the mean estimate is used for annual reporting. The number reported for the sampled pools is adjusted based on the confidence in the estimate of the carbon. The sampling error is calculated for each of the sampled pools at the 90 percent confidence interval and subsequently calculated as a percentage of the mean, using the following steps:

Step 1: Calculate the mean and the standard error of the inventory estimate (for each pool or combined pools where applicable, such as with standing live and dead wood).

Step 2: Multiply the standard error by 1.645.

Step 3: Divide the result in Step 2 by the total inventory estimate and multiply by 100. This establishes the sampling error (expressed as a percentage of the mean inventory estimate from field sampling) for a 90 percent confidence interval.

The per-acre unit should be expanded to the project area based on the number of acres in the project. The sum of onsite metric tons CO_2e for the project is input into the calculation worksheet for annual reporting.

2.10.1 Applying a Confidence Deduction to Sampled Estimates

Any forest carbon inventory derived from sampling will be subject to statistical uncertainty. Where statistical confidence is low, there is an increased risk of overestimating a project's actual carbon stocks and therefore a higher risk of over-quantifying GHG reductions and removals. To help ensure that estimates of GHG reductions and removals are conservative, Project Sponsors are required each year to apply a confidence deduction to the inventory of actual onsite carbon stocks. A confidence deduction is *not* applied to the forest carbon inventory when it is used to model baseline carbon stocks. Confidence deductions are applied, where appropriate, to estimated onsite forest carbon stocks each reporting period.

The target sampling error for the combined inventory estimates for non-aggregated projects is +/- 5 percent of the mean at the 90 percent confidence interval. Projects that cannot meet this target level are still eligible, but may have to take a "confidence deduction" that reduces their net reported carbon stocks.

The process for calculating the combined sampling error at the 90 percent confidence interval is shown above. The combined sampling error should be compared to the table below to determine the confidence deduction for the reporting period in which a site visit verification has occurred. The confidence deduction shall not be modified in the interim years between site visit verifications. The percent deduction from the table below is input into the calculation worksheet which calculates the net reported onsite stocks.

Table 2.10. Forest Carbon Inventory Confidence Deductions Based on Level of Confidence in the Estimate Derived from Field Sampling

Sampling Error (Percent of Inventory Estimate)	Confidence Deduction
0 to 5%	0%
5.1 to 19.9%	(Sampling Error – 5%) to the nearest 1/10 percentage
20% or greater	100%

The confidence deduction should be updated each time the project is subject to a site visit verification but should remain unchanged between verification site visits. If increased sampling over time results in a lower confidence deduction at the time of a site visit verification, the lower deduction may be applied to inventory estimates in all previous years. RGGI will issue CO_2 Offset Allowances in the current year for any increase in quantified GHG reductions and removals in prior years associated with the new (lower) confidence deduction. Conversely, if a loss of qualified sampling plots results in a higher confidence deduction, this higher deduction should also be applied to inventory estimates in all previous years. Any resulting decrease in creditable GHG reductions and removals for prior years will be treated as an avoidable reversal. State RGGI Regulations define reversals and establish requirements that apply after a reversal occurs.

2.11 Requirements for Calculating Carbon in Harvested Wood Products

A portion of the carbon in harvested trees continues to be sequestered for long periods of time as wood products. Standardized guidance is provided in Appendix C of the protocol to account for forest carbon that remains sequestered in harvested wood products. The protocol bases the accounting of harvested wood products on the average amount of carbon sequestered over a 100-year period. The 100-year period is consistent with the protocol's definition of permanence. The average amount of carbon remaining sequestered over the 100-year period is determined by calculating the amount of carbon delivered to the mills, calculating the portion of the carbon that is converted to wood products using a coefficient that estimates the mill's efficiency, and determining the wood product classes manufactured by the mill, as different wood products have different decay rates.

An estimate of the average carbon remaining in use over the 100-year term is provided for each wood product class, which is the basis of baseline and annual reporting of harvested wood products. Furthermore, some wood products eventually end up in landfills where anaerobic conditions serve to reduce the rate of further decomposition. Since the amount of harvested wood products that end up in landfills and the actual decay rate of the wood products in landfills are highly uncertain, the accounting of harvested wood products in landfills is included only when it is conservative to do so. Conservative in this case means that if, in a given reporting year, the amount of harvested wood products in the baseline exceeds the amount of harvested wood products in the project activity, the carbon in landfills is reported. If there is more harvesting of wood products in the project case than in the baseline case, harvested wood products in landfills are not considered in either the baseline or the project case.

RGGI has developed a spreadsheet tool to assist in the calculation of harvested wood products, which is available on www.rggi.org. The Harvested Wood Products Calculation Worksheet contains step by step instructions for its use. Project reporting of harvested wood products occurs on an annual basis. While the volume of logs delivered to the mill in the baseline case remains static throughout the project life, the mill efficiencies and the wood product classes identified in a reporting period are applied to the baseline harvested wood products the same way that they are applied to the project harvested wood products. The intent of this policy is to provide the best comparison of project activity to baseline activity possible.

The spreadsheet is designed with default values for converting volumetric units from logs delivered to mills to cubic feet and the values of mill efficiencies to be used on a geographic basis. The annual reporting of carbon in trees harvested for wood products is based on the relative proportion of volume in trees harvested for wood products and volume delivered to the mill(s) in the baseline case. Therefore, the reporting of volume delivered to mills is essential to calculating the volume in trees harvested for wood products.

Mill efficiency estimates from the actual mills where the project logs are delivered can be used if verifiable data exist to support the claim. Users should identify the mill(s) and input the volume that is manufactured into lumber, softwood plywood, oriented strand board, non-structural panels, miscellaneous products, and paper/pulp. Project Sponsors should provide an affidavit from the mill that the reported wood product classes are reasonable according to production records at the mill, unless they use the default product classes provided in the Assessment Area Data file available on www.rggi.org. Again, the wood product classes reported for a given reporting year apply both to the project and the baseline case, which eliminates the calculation of project benefits or detriments based on comparisons of the decay rates of wood products alone.

3 Modeling Carbon Stocks

This protocol requires the use of certain empirical models to estimate the baseline carbon stocks and project stocks of selected carbon pools within the project area. These models may also be used to supplement assessments of actual changes in carbon stocks resulting from the forest project.

3.1 Models and their Eligibility for Use with Forest Projects

Empirical models are used for estimating existing values where direct sampling is not possible or cost-effective. They are also used to forecast the estimations derived from direct sampling into the future. Field measurements (standing live and dead trees) provide the base input data for these models. Project Sponsors should be careful to ensure that all required data inputs for the models are included in the inventory methodology.

The models that simulate growth projections have two basic functions in the development and management of a forest project. Models project the results of direct sampling through simulated forest management activity. These models, often referred to as growth and yield simulation models, may project information regarding tree growth, harvesting, and mortality over time – values that should ultimately be converted into carbon in an additional step. Other models may combine steps and estimate tree growth and mortality, as well as changes in other carbon pools and conversions to carbon, to create estimated projections of carbon stocks over time.

Models are also used to assist in updating inventory plots so that the plots can represent a reporting year subsequent to their actual sample date. The model simulates the diameter and height increment of sampled trees for the length of time between their sampled date and the reporting year. Plot data can be projected for the length of time the projection method is expected to accurately reflect actual forest growth. Inaccurate updating of plot data can lead to the inability of a project to be verified. Verifiers are directed to randomly select plots or stands for verification. If the Project Sponsor's estimates deviate from the verifier's measurements, the verification will fail. Hence, it is recommended to update plots at least every 12 years.

The following growth models have been approved:

- CACTOS: California Conifer Timber Output Simulator
- CRYPTOS: Cooperative Redwood Yield and Timber Output Simulator
- FVS: Forest Vegetation Simulator
- SPS: Stand Projection System
- FPS: Forest Projection System
- FREIGHTS: Forest Resource Inventory, Growth, and Harvest Tracking System
- CRYPTOS Emulator
- FORESEE

A Project Sponsor may update inventory plot data for estimating diameter and height growth by incorporating data obtained from sample plots, as in a stand table projection. An example of an appropriate method of applying a stand table projection is as follows:

1. The project area is stratified into even-age management and uneven-age management.
2. Diameter increment shall be based on the average annual increment of a minimum of 20 samples of radial growth for diameter increment for each 8 inch diameter-at-breast-height (DBH) class, beginning at 0 to 8 inch DBH for each management type (even-age or uneven-age). The average annual increment shall be added for each year according to the plot's sample date.
3. Height increment is based on regression curves for each management type (even-age or uneven-age) developed from height measurements from the same trees the diameter increment data was obtained. The estimated height shall be determined using the regression estimators for the 'grown' diameters as described above.

RGGI may include additional models following approval of a state forestry authority (i.e. a state agency responsible for oversight of forests) who will acknowledge in writing that the model:

- Has been peer reviewed in a process that 1) primarily involved reviewers with necessary technical expertise (e.g. modeling specialists and relevant fields of biology, forestry, ecology, etc.), and 2) was open and rigorous
- Is parameterized for the specific conditions of the project area
- Limits use to the scope for which the model was developed and evaluated

- Is clearly documented with respect to the scope of the model, assumptions, known limitations, embedded hypotheses, assessment of uncertainties, and sources for equations, data sets, factors or parameters, etc.
- Underwent a sensitivity analysis to assess model behavior for the range of parameters for which the model is applied
- Is periodically reviewed

3.2 Using Models to Forecast Carbon Stocks

The use of simulation models is required for estimating a forest project's baseline carbon stocks. Models may also be required to forecast actual carbon stocks expected under the forest project (e.g. in conjunction with determining expected harvesting volumes or in updating forest carbon inventories).

Standing live tree information should be incorporated into the simulation models to project carbon stocks over time. If a model has the ability to convert biomass to carbon, it should include all the carbon pools required by this protocol. Standing dead trees should be assumed to be static over the baseline modeling. Exceptions to this rule are allowed if approved in writing by RGGI prior to verification.

Projected baseline carbon stocks should be portrayed in a graph depicting time in the x-axis and metric tons of carbon in the y-axis. Baseline carbon stocks should be projected forward from the forest project's start date. The graph should be supported with written characterizations that explain any annual changes in baseline carbon stocks over time. These characterizations should be consistent with the baseline analysis required in Section 6 of the protocol.

3.3 Modeling Requirements

A modeling plan should be prepared that addresses all required forecasting of baseline carbon stocks for the forest project. The modeling plan shall contain the following elements:

1. A description of all silviculture methods modeled. The description of each silviculture method will include:
    a. A description of the trees retained (by species groups if appropriate) at harvest.
    b. The harvest frequency (years between harvests) for each silviculture method modeled.
    c. Regeneration assumptions.
2. A list of all legal constraints that affect management activities on the project area. This list should identify and describe the legal constraint, how the legal constraint affects the project area, and discusses the silviculture methods that will be modeled to ensure the constraint is respected.
3. A description of the site indexes used for each species and an explanation of the source of the site index values used.
4. A description of the model used and an explanation of how the model was calibrated for local use, if applicable.

Modeling outputs should include:

1. Periodic harvest, inventory, and growth estimates for the entire project area presented as total carbon metric tons and carbon metric tons per acre.

2. Harvest yield streams on modeled stands, averaged by silviculture method and constraints, which should include the period over which the harvest occurred and the estimated CO_2e of wood (CO_2e in logs delivered to mills) removed.