



# Verifying Enhanced Forest Carbon Inventories

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OLI & GMUG Joint Meeting April 21-22, 2026

# ABOUT SCS GLOBAL SERVICES

SCS is an international leader in third-party environmental and sustainability certification and standards development.

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certifications**

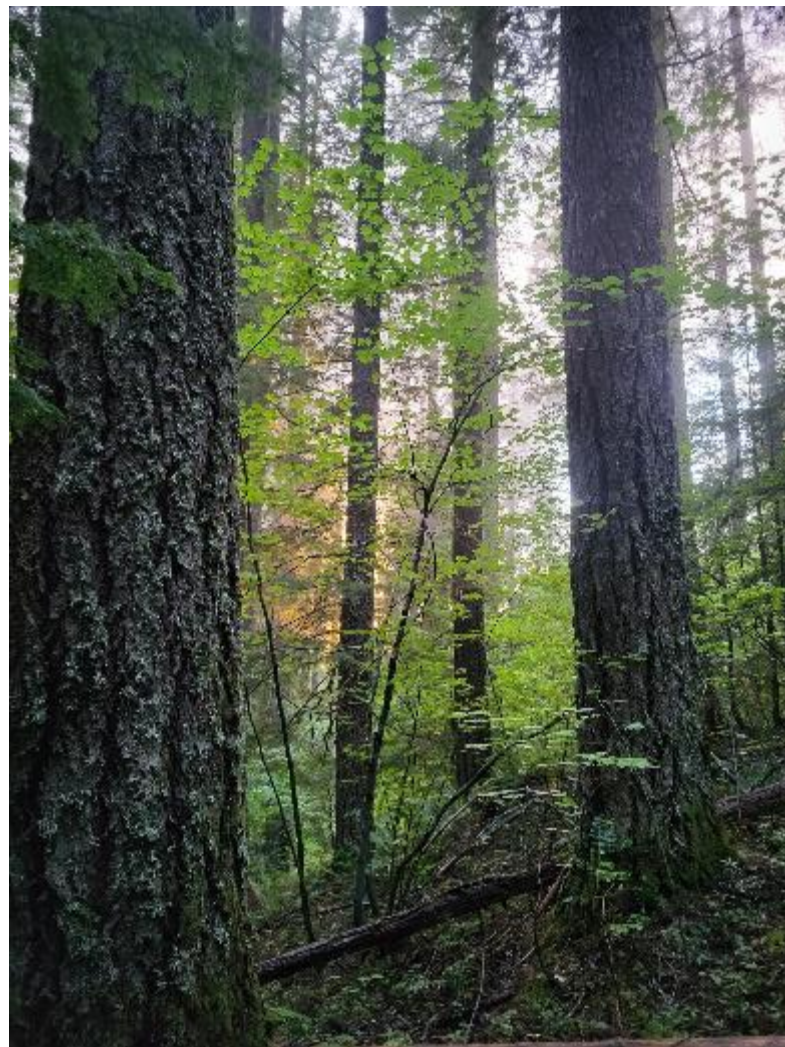
**Auditors  
in all major  
markets**



*\*SCS stands for Scientific Certification Systems*

# Improved Forest Management (IFM)

- Most common forest carbon offset project type in the U.S.
- Project activities include:
  - Reduced timber harvest
  - Deferred timber harvest
  - Lengthened rotation age
- Other forest carbon project types include:
  - Afforestation, Reforestation, Revegetation (**ARR**)
  - Reduced Emissions from Deforestation and Degradation (**REDD+**)
  - Urban Forestry



# Registries and Methodologies



- Compliance
  - State of Washington
  - State of California
  - Others in Canada, EU, Australia, etc.



- Voluntary
  - American Carbon Registry (ACR)
  - Verified Carbon Standard (VCS)

# Components of Carbon Project

- Current Condition → Inventory
- Baseline → Modeling
- Project Action → Monitoring
- Quantification → Accounting
- Verification → Auditing

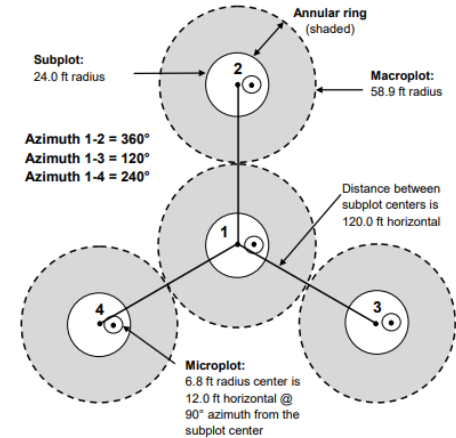


Figure 0-1. FIA Phase 2 plot diagram. See individual Phase 3 chapters for Phase 3 plot figures.



**Table 1: Core GHG Accounting Principles**

<b>RELEVANCE</b>	Select the GHG sources, GHG sinks, GHG reservoirs, data, and methodologies appropriate to the needs of the intended user.
<b>COMPLETENESS</b>	Include all relevant GHG emissions and removals. Include all relevant information to support criteria and procedures.
<b>CONSISTENCY</b>	Enable meaningful comparisons in GHG-related information. Use consistent methodologies for meaningful comparisons of emissions over time. Transparently document any changes to the data, boundary, methods, or any other relevant factors.
<b>ACCURACY</b>	Reduce bias and uncertainties as far as is practical.
<b>TRANSPARENCY</b>	Disclose sufficient and appropriate GHG-related information to allow intended users to make decisions with reasonable confidence. Disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used.
<b>CONSERVATIVENESS</b>	Use conservative assumptions, values, and procedures to ensure that GHG emission reductions or removals are not overestimated.

<https://acrcarbon.org/wp-content/uploads/2023/10/ACR-Standard-v8.0.pdf>

FRAMEWORK FOR

# REMOTELY SENSED QUANTIFICATION OF FOREST CARBON

VERSION 1.0

March 2026



<https://acrcarbon.org/wp-content/uploads/2026/03/Framework-for-Remotely-Sensed-Quantification-of-Forest-Carbon-20260327.pdf>

# ACR's Approach in a Nutshell

- Initial Inventory ← Traditional Inventory...Why?
- Modeling ← Treelist inputs required!
- Monitoring ← Remote Sensing!
- Accounting ← Still Death by Excel!
- Auditing ← Third Party VVB + Registry Review

# How does ACR Want it Done?

## Match Pixels to Plots in the field

- ◆ Do a field validation plot, co-register it to the corresponding pixel, and compare the biomass prediction to the field plot estimate
- ◆ Repeat this 30 times at random locations across the project area
- ◆ If the difference is within a set error tolerance (say  $\pm 10\%$ ), then I feel pretty dang good about the model

# Other Options

Aggregate pixels to stand, strata, or project level?

- ◆ I have done this in the past
- ◆ What is the appropriate level to aggregate to?
- ◆ How to aggregate uncertainty?
- ◆ What are some potential pitfalls?

What are some other ideas?

→ VERRA and CARB Examples

→ Takeaway

### Equation 3: Root Mean Squared Error

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$$RMSE_i = \sqrt{\frac{\sum_{n=1}^{N_{VP,i}} (C_{AG,VP,i} - \bar{C}_{AVE,AG,p,VP,i})^2}{N_{VP,i}}}$$

### Equation 4: Uncertainty Percentage using Root Mean Squared Error

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$$UNC_{RMSE,i} = \left( \frac{RMSE_i}{\bar{C}_{AG,i}} \right) \times 100\%$$

### Equation 5: 90% Confidence Interval

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$$CI_i = \left( \frac{RMSE_i}{\sqrt{N_{VP,i}}} \right) \times 1.645$$

### Equation 6: Uncertainty Percentage at 90% Confidence Interval

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$$UNC_{CI,i} = \left( \frac{CI_i}{\bar{C}_{AG,i}} \right) \times 100\%$$

A Predictive Model is deemed to be in statistical agreement with Validation Plots, and hence eligible for deriving and reporting carbon stocks and uncertainty for its AOI, when the following conditions are met:

- The uncertainty percentage using RMSE ( $UNC_{RMSE,i}$ ; Equation 4) is less than 20% (i.e., root mean squared error is less than 20% of the mean aboveground carbon density for relevant pools), and
- The uncertainty percentage using the 90% confidence interval ( $UNC_{CI,i}$ ; Equation 6) is equal to or less than 10% (i.e., the confidence interval is equal to or less than 10% of the mean aboveground carbon density for relevant pools).



**Thank you!**

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# Key ACR Takeaways

- Validation Plots are “managed” by ACR
- Can use multiple models in project, but have to be spatially explicit.
- Can revert between traditional and remote
- Prediction must be continuous CO<sub>2</sub>e (biomass)
- Project does validation, VVB verifies validation plots

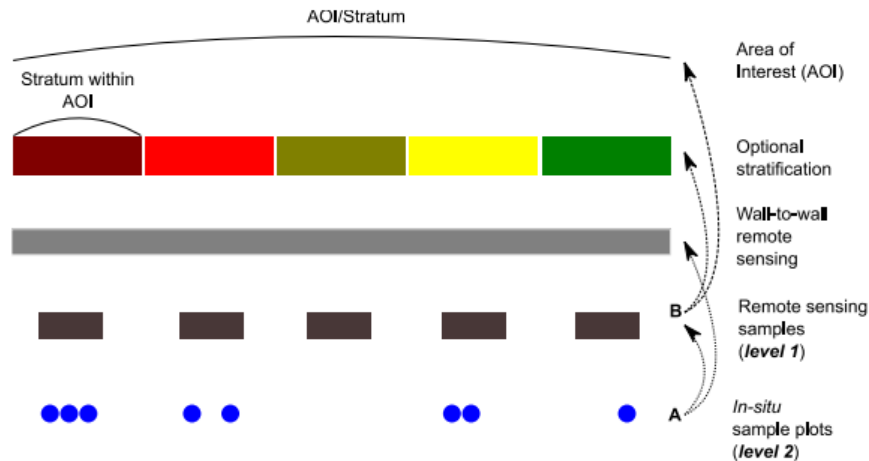
# Other examples

- Stand-based “unpaired” example
- Simple HT:Biomass regression from CHM (Verra/VCS)
- NFI “interpolation” based on cover maps (Verra/VCS)

## VT0005

## Tool for measuring aboveground live forest biomass using remote sensing

**Figure 1:** Schematic Diagram of Procedure Specified in this Tool to Estimate ALFB Density for Strata or AOI from Systematic and Random RSSUs and CP and VP plots



**A** uses ALFB density in measured in-situ plots to calibrate RS data.

**B** estimates ALFB density at the stratum or AOI level based on RS sampling

<https://verra.org/wp-content/uploads/imported/methodologies/VT0005-Tool-for-measuring-ALBF-using-remote-sensing-v1.0.pdf>

### 5.1.3.3 Step 3c: Estimation of ALFB at the Stratum/AOI

In a general case with forest stratification and different RS-ALFB allometric relations for each stratum, the estimator specified below must be used to estimate the mean and variance for each stratum and project area (Asner *et al.* 2013; Nelson *et al.* 2012; Næsset *et al.* 2013). Assuming  $n$  strata, and  $n_j$  remote sensing sampling units (RSSU) within each stratum  $j$ , the estimator for the mean value of ALFB and the variance for stratum  $j$  are:

$$ALFB_j = \frac{\frac{1}{n_j} \sum_{i=1}^{n_j} F_{ij}(\alpha_j)}{\frac{1}{n_j} \sum_{i=1}^{n_j} \eta_{ij}} \quad (13)^8$$

$$\widehat{ALFB} = \sum_{j=1}^N w_j ALFB_j \quad (14)^9$$

$$\sigma_j^2 = \frac{1}{\bar{\eta}_j^2} \frac{\sum_{i=1}^{n_j} (F_{ij}(\alpha_j) - ALFB_j \eta_{ij})^2}{n_j(n_j - 1)} + \frac{1}{\bar{\eta}_j^2} \sum_{k_1}^{P_j} \sum_{k_2}^{P_j} Cov(\alpha_{k_1j}, \alpha_{k_2j}) \overline{F'_{k_1j}} \overline{F'_{k_2j}} \quad (15)^{10}$$

$$\bar{\eta}_j = \frac{1}{n_j} \sum_{i=1}^{n_j} \eta_{ij} \quad (16)^{11}$$

<https://verra.org/wp-content/uploads/imported/methodologies/VT0005-Tool-for-measuring-ALBF-using-remote-sensing-v1.0.pdf>

# As an Auditor

## What I need →

- ◆ A way to independently verify your inventory

## What I DON'T need →

- ◆ To reinvent the wheel
- ◆ To get stuck in never-ending rabbit holes
- ◆ To spend an unreasonable amount of time and YOUR money getting bogged down in the weeds

## What I actually care about →

- ◆ Getting to a “reasonable level of assurance”
- ◆ Making sure the end result, i.e. the part that the \$\$ is based on, is reasonably accurate (or at the very least conservative)

# Components of Carbon Project

## 20-yr Baseline and Project CO<sub>2</sub>e

